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Poles Apart

Discerning And Opportunistic Mind-sets In Design Learning

by Basyarah Hamat

Poles Apart:
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Basyarah Binti Hamat

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Discerning and opportunistic mind-sets in design learning

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"Of learning designers, in face of frustrations,
When delving into wicked and complex situations,
Their young minds embedded with misconceptions,
Requiring correcting and sometimes rejections.

Though some are not, ever unyielding,
Are open to reflecting and intuitive sense making,
Others remain fixated, concealed from insights,
Focussing only on what the teacher highlights.

Alas, what steers these minds, in the right direction,
Remains elusive and calls for investigation,
To augment our understanding, of design learning,
So we can provide guidance and supportive nurturing.

Thus, with grounded coding and standard deviations,
To factor analyses and correlations,
Mind-sets transpire as a gentle reminder
To enlighten and cultivate well-rounded designers."

' June 2016

Contents

Summary

Mind-sets play an important role in orienting the decisions and activities that an individual engages in when he or she is designing, and designing involves interaction with complex, open-ended and ambiguous situations. This means that the individual disposition of a person influences the way that he or she reacts. In designing, the complexity of the conditions that the individual interacts with, can increase due to the nature of the design problems. Additionally, the processes that an individual engages in while designing is in turn, expected to influence the quality of design solutions that he or she produces.

This thesis focusses on investigating the phenomena of mind-sets in the context of design and design learning. In Chapter 1, a detailed overview of the direction, approach and structure of this thesis is presented. This thesis addresses four research questions. The first research question aims to examine the prevalent mind-sets that design students have toward design learning and how these mind-sets can be identified. In Chapter 2, literature in the fields of education and psychology that are related to mind-sets in design learning are discussed. Mind-set as defined in this thesis is introduced, and selected variables which facilitate the process of examining mind-sets in design learning are presented. These variables are mapped out in a conceptual framework established after the Presage-Process-Product (3P) model of students' learning after Biggs (1993). This conceptual framework forms the basis for examining and testing mind-sets in design learning for the three following empirical studies. In Chapter 3, three variables encompassing students' learning conception (the internal aspect of mind-set); and preference for instruction and preferred learning approach (the external aspects of mind-set) are examined. Design students were interviewed and asked to fill in a questionnaire. The qualitative and quantitative data sets were cross-validated, and two categories of mind-sets are proposed: the discerning and opportunistic mind-sets.

In Chapter 4, the second study is presented. This study aims to externally validate the two mind-set categories which were proposed in the first study. Other factors that are associated to the adoption of the discerning and opportunistic mind-sets are examined (second research question). Differences between the two mind-sets in terms of perceived self-efficacy, tolerance for ambiguity, view of own intelligence and preferred learning approaches were found. The relation between mind-sets, design processes and design outcomes were also examined (third research question). Design students filled in a questionnaire and were asked to solve a design problem. Questions that students asked regarding the design problem provided insights regarding their design process, while an evaluation of the solutions that they generated provided

insights regarding the quality of outputs that they could produce. Additionally, the influence of design theory-oriented stimuli on the performance of design students in terms of processes and outcomes are examined (fourth research question).

Effects of the stimuli on the two mind-sets were not observed in the second study, therefore an improved experimental set-up was attempted in the third study. A reflection-oriented stimuli was used to test whether the design activities and design outputs produced by design students that incline toward the two different mind-sets, could improve. Additionally, a questionnaire was developed based on the two previous studies to assess the mind-sets. The two mind-sets were tested on all three levels of the presage, process and product levels again. Results of the third study is presented in Chapter 5. Distinct differences in between the two mind-sets were found, supporting for the categorisations of mind-sets in design learning. In Chapter 6, findings from the three empirical chapters are summarized and the theoretical contributions are presented. Implications and recommendations for design education and limitations of these studies are also discussed.

Acknowledgements

بسم الله الرحمن الرحيم

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1

Introduction

1.1 Mind-sets in design learning

Designing requires interaction with unclear, inexplicit and ambiguous problem solving situations that are also complex, non-routine and ill-defined (Dorst & Cross, 2001; Lawson, 2006). In learning to design, students are engaged with a broad spectrum of fields. Courses range from subjects like statics and material engineering; to sketching and design aesthetics; and to marketing and innovation processes (Ulrich and Eppinger 2007; Thomke & Nimgade, 2000). Students are faced with a relatively diverse set of subjects to learn. Thus, they need to develop distinct skill sets in order to learn to design (Casakin & Kreitler, 2011; Cross, 1990; Kokotovich, 2008; Williamson, 2011). To successfully solve ill-defined problems, students are recommended to develop their cognitive (Goel, 1992; Kim & Kim, 2015; Mayer, 2001; Rivka, 2001), metacognitive (Goldschmidt, 2001; Casakin, 1999; Magno, 2010) and motivational skills (Mayer, 2001; McCombs, 1988).

Cognitive skills are related to the capability to accomplish operations that are associated to a specific domain (Mayer, 2001). For example, in learning mathematics, this involves being able to perform basic operations such as adding, subtracting, dividing and multiplying. In learning to write, it involves spelling words correctly and structure grammatically correct sentences. In learning design, it ranges from carrying out SWOT analyses (an analysis undertaken to identify the strengths, weaknesses, opportunities and threats pertaining to a particular person, company, product etc.) in order to explore related contexts, to making customer journey maps for framing insights, and making concept sketches to generate or illustrate ideas (Boeijen et al., 2014; Kumar, 2013). Metacognitive skills, on the other hand, are related to knowledge of strategies to manage the cognitive knowledge. That is, it is associated to distinguishing when a specific method or information should be applied (Mayer, 2001; McLaren & Stables, 2008). It involves the ability to recognize appropriate strategies and are concerned with identifying and structuring design problem (Mayer, 2001). The design student should be able to distinguish key observations and summarize the important findings when exploring related design contexts. This skill is associated to the capacity of the student to plan or organise, make judgements, decisions and manage the process of designing (Vinod, 2001). This skill interacts with an individual's dispositions such as "…personality, social skills and self-discipline" (Vinod, 2001, p. 222).

Motivational skills are related to feelings and beliefs or mind-sets that design students have about their interest and ability to solve design problems (Mayer, 2001). A student who is interested and confident of their own capabilities will be more likely to have the will to solve complex design problems (Dweck, 1986; Mangels et al., 2006; Mayer, 2001). Students achieve better outcomes when they engage in self-regulatory behaviour to improve their learning (Christensen et al., 2002). This means that students can and will regulate their learning activities in order to seek for understanding and endeavour toward successful design solutions. Contrastingly, even if a design student is well equipped in terms of cognitive and metacognitive skills, successful outcomes in problem solving situations are less likely when they lack motivational skills (Dweck, 1986; Mangels et al., 2006; Mayer, 2001). Motivational skills in design learning are, therefore, central to facilitating autonomous learning in students.

Researchers in the design field have, thus far, focussed on investigating cognitive and meta-cognitive aspects of the design student. For instance, efforts have been focussed on expanding cognitive knowledge related to design methods and processes (Boeijen et al., 2014; Christiaans & Dorst, 1992; Jones, 1992; van Dijk & Hekkert, 2014), reflective models in design learning (Smith et al., 2009) and typologies of project methods (Lee, 2009). Other researchers examine metacognitive aspects of design learning to enhance the deployment of appropriate design strategies. For example, through empirical studies, Rivka (2001) propagated the use of a process model in order to assist students in making their knowledge structures explicit. Additionally, Goldschmidt (2001) investigated how to enhance the process of construction and re-iteration of design concepts using visual analogy as a strategy. However, even though students are taught design methods, they need to also have a *method mind-set* in order to use the methods effectively (Andreasen, 2003; Daalhuizen et al., 2014). The *method mind-set* is related to having "the proper understanding of a method's use in accordance with the designer's reality (interpretation of task, situation, execution, validation, etc.), and the method's background and proper use." (Andreasen et. al, 2015, p. 57). It is propogated because methods and their applications encompass diverse aspects that need to be comprehended prior to their usage. Design methods encompass a constituent, yet specific part of design learning. However, mind-sets are a part of motivational skills (Mayer, 2001). They encompass internal mental dispositions and external behavioural responses that determine an individual's reaction or approach to design learning in general (Dweck, 2006). Furthermore, they play a vital role in ensuring the success of students' learning (Dweck, 1986; Mangels et al., 2006; Ravenscroft et al., 2012).

Research on motivational skills in design education and learning, are however, scarce. Furthermore, current design education focusses on the development of cognitive and metacognitive skills. This is not necessarily sufficient for students' design learning. I thus propose to examine the mind-sets that students hold in design learning. In this thesis, three empirical studies concerned with examining students' mind-sets in design learning are presented.

1.2 Research questions, objectives and relevance

Four main research questions are formulated to investigate the mind-sets that students hold in design learning. These research questions form a foundation that underpins the ensuing studies presented in this thesis. Such an investigation begins by firstly defining mind-sets in design learning. The first research question was formulated as follows:

> *1) Are there prevalent mind-sets that design students have toward design learning and how can they be identified?*

The goal of the first research question was to begin by identifying the types of mind-sets that prevail in design learning. This is expected to allow for subsequent and structured investigation of factors that are related to the adoption of the distinct mind-sets. Additionally, it allows for the testing of the related effects that mind-sets have on the design processes that students engage in along with the outcomes that they produce. Accordingly, the following research questions were formulated:

> *2) What other factors are associated to the adoption of certain types of mind-sets?*
> *3) And are these mind-sets related to the design processes that students engage in and the outcomes that they produce?*

A further interesting aspect to examine is the potential to improve the performance of design students, that is when they incline towards a certain mind-set. Are there any forms of subtle interventions that can be conducted to augment the performance of design students? Performance here denotes the behaviours that students display throughout engaging in the design process and also, the quality of design outputs that they produce. The final research question was thus framed as follows:

4) Can interventions be applied to positively influence the performance of design students in design learning?

The four research questions build upon one another and serve to expand knowledge on the types of mind-sets that prevail in design learning. Additionally, they serve to uncover differences between the mind-sets in terms of the design processes that students engage in and the outcomes that they produce. This knowledge potentially supports the improvement of design learning and teaching.

This research contributes to the existing body of knowledge by specifically investigating how design students internalize and externalize design learning. By examining their mind-sets, a deeper understanding is gained of how design students deal with the complex and diverse learning situations that they are faced with. A major outcome of this thesis is the development of a categorisation of design learning mind-sets. The types and characteristics of mind-sets that prevail amongst design students that are uncovered, provides the means of investigating other factors that may be associated to these mind-sets. Additionally, it allows for design teachers and students to actively manage the impending challenges of design learning. For design teachers, a different way to reflect upon and manage their students' strategies in learning design is provided. For design students, the categorisations assists in enabling them to contemplate and regulate their own mind-sets in design learning. Finally, findings presented in this thesis contribute to research in the area of motivational skills in design learning.

1.3 Research approach

Interactions between input, process and output related factors of specified research contexts have commonly been analysed and described using Input-Process-Output (IPO) models. For example, the IPO model has been used to analyse factors that influence the success of design projects (Badke-Schaub, 1999) and also team effectiveness (Salas et al., 2009). A similar, yet more specific model to examine the topic of mind-sets in design learning, can be found in Biggs' 3P model. This model focusses on factors that relate to student learning, and is adapted as a conceptual framework of this thesis.

The 3P model consists of factors that are situated within three different levels: the *presage*, *process* and *product* levels. Similar to the IPO model, factors on the *presage level* assess input related factors. *Presage* is defined as indicators that predict forthcoming circumstances ("Collins English Dictionary - Complete & Unabridged 10th Edition," 2009, "Online Etymology Dictionary," 2010; The Free Dictionary Online, 2016a). In this thesis, variables situated on the *presage level* are factors which are related to the student, that exist prior to student-teacher interactions (Biggs, 1993, 2012). It is expected that variables on the *presage level* can influence the outcome of variables on the two preceding levels: the *process* and *product* levels. On the *process level*, variables related to the responses that students make during their engagement in design tasks are assessed. On the *product level*, the quality of outputs produced by students from their engagement in design tasks are evaluated.

The conceptual framework used in this thesis assesses the same three levels of the 3P model. Appropriate factors on the three different levels were identified through a review of the extant literature (see Section 2.3 for further details). The variables situated on the three different levels of the conceptual framework are examined throughout three subsequent empirical studies. The analyses of all three studies were in one way or other triangulated using both qualitative and quantitative data sets, instead of using only quantitative or qualitative data. By doing so, concrete and plausible interpretations of the findings could be made, leading to deeper understanding of the mind-sets. Furthermore, by using both quantitative and qualitative approaches in these studies, the potential of both methods could be maximised (Creswell, 2014).

The three empirical studies are designed to identify the types of mind-sets that prevail within design students, test the reliability and extend the description of characteristics of the mind-set personifications. Additionally, the empirical studies are designed to assess the possibilities of improving design learning through subtle mind-set interventions. For an overview of the set-up for each study, see Figure 1.1.

An exploratory study was conducted in Study 1. The main objective was to explore, identify and describe the prevalent mind-sets in design learning. An explanatory-sequential mixed method research study was used for this purpose. Data was collected using an adopted version of the *Approaches and Study Skills Inventory for Students* (Entwistle et al., 1997). The variables on the presage level of the conceptual framework were identified through the questionnaire data and semi-structured interviews. The data obtained from the questionnaire was quantitatively analysed and subsequently validated with data from existing literature and the semi-structured interviews, which were analysed qualitatively (Creswell, 2014; Johnson & Onwuegbuzie, 2004). A validation of these data sets consequently account for the distinctively significant types of mind-sets (see Study 1 in Chapter 3).

The next two studies were meant to expand more vividly the description of mind-sets in design learning. The two mind-sets from Study 1 were validated in Study 2. The main objective was to investigate individual dispositions of the design student that are associated to the mind-sets that they adopt (see Sections 2.3.1.4 for details of the variables associated to individual dispositions). A questionnaire was used for this purpose. Respondents were divided into two groups: control (did not receive probe) and experimental (received probe). Both groups filled out the questionnaire that assessed their individual dispositions and completed a 1-hour design task. The interactions between students' self-reported individual dispositions, the behaviours that they adopted in their design process and the quality of outcomes that they produced, when they inclined toward a distinct mind-set in design learning, were compared. Students in the experimental group received an intervention to test whether their performance could be improved (see Section 4.4). The effects of the probe for students in the experimental and control conditions could also be compared.

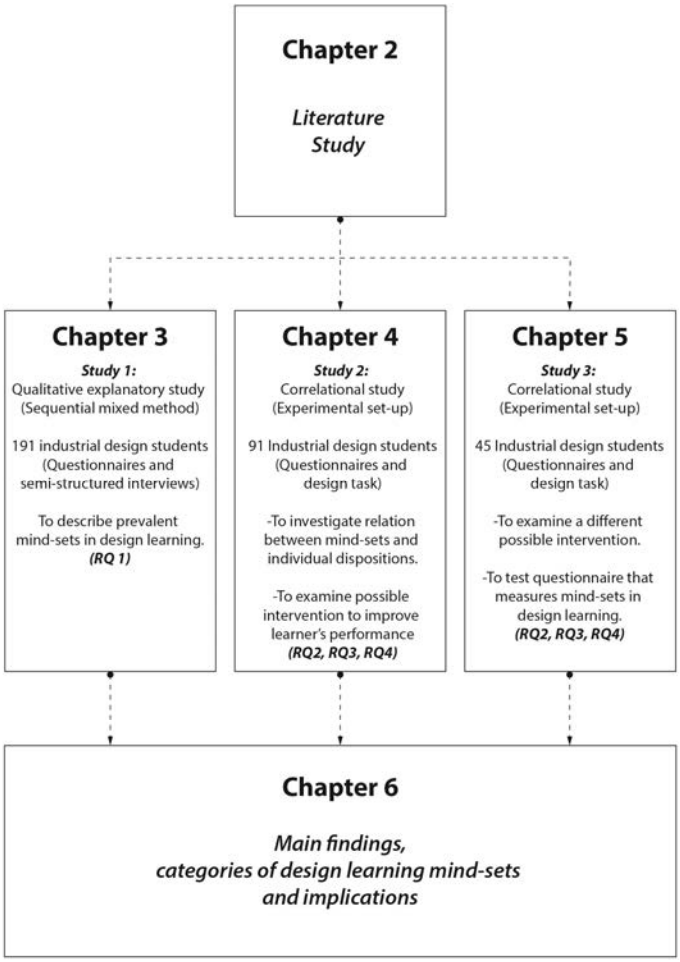

Figure 1.1 Overview of the three studies conducted

Study 3 adopts a similar design set-up as the previous study. However, two improvements were made to the research set-up. Firstly, the questionnaire that was used to measure mind-set in this study was drawn up based on findings from the two previous studies. Secondly, a different yet simpler method of intervention was used to investigate whether the performance of students' could be improved (see Section 5.3.4).

1.4 Structure of this thesis

An overview of the chapters in this thesis is illustrated in Figure 1.1. In Chapter 2, the conceptual framework that was established based on the literature study that was conducted is presented. The chapter begins with examining the term mind-set in the context of design learning. Here, literature from the education and psychology fields are drawn upon. Subsequently, six constructs that build the conceptual framework of this thesis are described. In Chapter 3 the findings of Study 1 are presented. This chapter essentially discusses the categories of design learning mind-sets that were established based on constructs from education literature. The process of developing the categories of mind-sets was based on a cross-validation of the questionnaire and interview data sets. In Chapter 4 the findings of Study 2 are presented and discussed. The design learning mind-set categories are extended by the integration of constructs from the psychology literature. The differences of design behaviours that students engage in throughout their design process and the quality of outcomes that they produce, when they incline toward the different design learning mind-sets, are also discussed in this chapter.

In Chapter 5, the findings of Study 3 are presented. The design learning mind-set categories are further distinguished based on mind-set scales that were built upon the two previous studies. Characteristic differences between the design learning mind-sets in terms of their engagement in their design process and the quality of outcomes that they produce are further expanded upon in this chapter. Additionally, the influence of an intervention that affected the different design learning mind-sets is presented. In Chapter 6 the thesis is concluded with a general discussion on the contribution of the three empirical studies to the theoretical body of knowledge and its practical impact on design education.

2

Defining and testing mind-sets in design learning

In this chapter a specific set of variables that allow for the examination of design learning mind-sets are identified. These variables are related to (1) factors that exist within students prior to their actual engagement in learning; (2) the process of designing that students engage in; and (3) the design outcomes that students produce. A review of the present literature suggests that these variables fit appropriately within the Presage-Process-Product (3P) model of students' learning after Biggs (1993). This model was thus adapted and used as a conceptual framework in this thesis. This conceptual framework forms the basis for examining and testing mind-sets in design learning for the three following empirical studies. The structure of this chapter is as follows. Firstly, a review of literature related to mind-sets in design learning will be discussed. Next, the original 3P model of students' learning and the adapted conceptual framework that is used in this thesis is presented. Finally, the related variables situated within the adapted conceptual framework are further discussed in this chapter.

2.1 Defining mind-sets in design learning

Often, a person's mind-set is described as being composed of two components. The first component encompasses a way of thinking, a mental attitude, inclination or disposition as well as opinions formed, belief, feelings and values (Cambridge Dictionaries Online, 2016; Oxford Dictionaries Online, 2016; The Free Dictionary Online, 2016). The second component encompasses an individual's interpretation of a situation and their intuitive tendencies to respond in a certain way (The Free Dictionary Online, 2016; Cambridge Dictionaries Online, 2016). This means that there is a more internal aspect to it, which pertains to a person's mind-set, as well as a more re-active part guiding responses to given situations.

Scientific literature similarly addresses both of these components, providing distinct measures and theories for their examination and explication. The first component of mind-sets is examined through so called self-implicit theories which are related to an individual's perception (or belief) of their own intelligence (Diener & Dweck, 1978, 1980; Dweck, 1986; Dweck, Chiu, & Hong, 1995; Grant & Dweck, 2003; Dweck, 2006; Donohue et al., 2012; Flores et al., 2011; Dweck, 2015). These studies suggest that depending on whether an individual views their intelligence as a permanent trait that cannot be changed (the so-called "entity theorists", see Mangels et al., 2006) or as a transformable trait that can be developed (i.e. "incremental theorists"), they can be categorised as having fixed or growth mind-sets, respectively. In relation to the second component of mind-sets, Dweck et al. (1995) argue that an individuals' goals, interpretations of situations and reactions to them are influenced by their mind-sets.

Building upon this notion and the previous studies discussed, it can be deduced that mind-sets encompass an interplay of internal mental dispositions and external behavioural responses. It is further argued in the literature that an individuals' reaction or approach to the situation of learning is, therefore, determined by their mind-set (Román et al., 2008; Rodriguez, 2009; Richardson et al., 2012; De-la-Fuente et al., 2015; Nelson et al., 2015). Translating this to the design learning context suggests that there is an interplay between a student's mental state and subsequent perception of a situation in which they learn design as a subject. This in turn can be expected to determine the responses that they bring forth in their design learning activities.

When examining mind-sets in learning design, we should be concerned with aspects of interpretations that play distinct, yet meaningful, roles towards students' responses in design learning situations. Design students are faced with complex and open-ended problem solving situations (Cross, 1982; Broadbent & Cross, 2003; Buchanan, 2016). These situations, by nature, require a variety of re-interpretations of the problem, its contextual dependencies and an almost infinite amount of related potential solutions (Rittel & Webber, 1973). This means that students are constantly faced with situations of varying levels of uncertainty and ambiguity which triggers responses based on their mental disposition, i.e. based on their mind-sets.

In order for teachers to help students manage their learning behaviour efficiently, it is therefore considered beneficial to investigate the influences and effects of design learning mind-sets in education. In order to examine the mind-sets of students in the specific context of learning in design, multiple factors that are interconnected to the complex setting of design learning should also be examined. Consequently, a conceptual framework is used to guide this investigation. The Presage-Process-Product (3P) model which is based on Biggs's (1993) model of student learning was adapted for this purpose. This model provides a general basis for examining variables that are expected to contribute to the investigation of mind-sets in design learning and is described in Section 2.2.

2.2 A conceptual framework of students' learning

Conceptual frameworks are used in research to explicate our perception of how things are connected (Cohen et al., 2007). Constructs can be created and hypothetical relationships between constructs can be organized, within a conceptual framework, to predict events prior to its actual occurrence (Cohen et al., 2007). However, it is difficult to explicate the components of such a framework for learning. Some argue that that it is challenging to distinguish between the relevant and multifaceted factors that influence the concept and processes involved in learning (McIlrath & Huitt, 1995; Olson & Hergenhahn, 2016). Yet, researchers have conceptualized initial models of teaching and learning that highlight the main factors that influence learning in classrooms (Carroll, 1963; Cruickshank, 1986; Biggs, 1993; Huitt, 2003). The '3P' model of student learning developed by Biggs (1993) was originally used in relation to teaching in classrooms by Dunkin & Biddle (1974). Biggs (1993), however, adapted the model to address students' learning (see Figure 2.1).

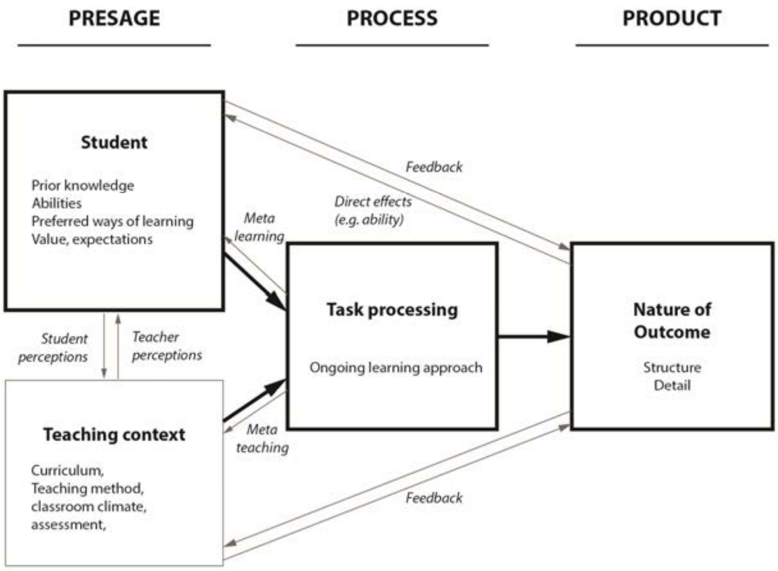

Figure 2.1 Biggs's (1993) 3P model of classroom learning

The 3P model comprises three different levels: (1) *presage*; (2) *process*; and (3) *product*. The *presage level* encompasses stable and contextual aspects that affect students' learning that exist prior to student/teacher interactions. Two factors are categorised on the presage level: student-related factors, on the one hand, and teacher-related factors on the other. Factors on the presage level predispose students' self-reported preference of approaches to learning on the process level, which, in turn, determine the outcomes they produce on the product level. Additionally, presage factors such as students' ability, directly affect outcomes, while outcomes provide feedback that in turn affects the student (Biggs, 1993). Subtle distinctions within the presage factors have been provided in research by, e.g., Cruickshank (1986) and Huitt (2003). For example, although Biggs (1993, 2001) and Huitt, (2003) recognizes students' prior knowledge and learning approach or style as sub-factors, Biggs (1993, 2001) includes students' ability as a sub-factor while Huitt, (2003) suggests motivation and intelligence as sub-factors and students' behaviour as a separate factor.

On the process level, researchers have examined the levels of mental processing that students engage in throughout their learning activities. Their levels of engagement have been observed to vary strongly (Zhang, 2000; Gijbels et al., 2005; Biggs, 2012; Kember et al., 2010; Reid et al., 2012; Han, 2014). This "level of engagement or depth of processing" applied during learning has been classified into the *surface* and *deep learning* approaches (Säaljö, 1979; Chin & Brown, 2000; Biggs et al., 2001; Entwistle & Smith, 2002; Entwistle & Ramsden, 2015). Other researchers have also examined the *strategic learning approach*. This approach refers to the combination of understanding and memorising (Kember, 2000, p. 104) or management of learning activities in terms of content or time (Entwistle, et al., 1997).

On the product level, researchers have examined learning outcomes using several distinct measures. Firstly and more commonly, researchers use indicators of academic achievement such as test scores or GPA levels (Zhang, 2000; Gijbels et al., 2005; Han, 2014). However, outcome measures such as students' engagement in classes and attendance levels have also been used (Han, 2014). Other researchers use self-evaluation data that assess other aspects of outcomes. This includes assessing the level of confidence that students have in attaining important learning goals (Kember et al., 2010) and the abilities of students, such as their analytical, creative and practical abilities (Zhang, 2000).

Constructs are not necessarily tied to any particular existing concept–phenomenon, but can instead be used to serve different purposes (Bannister & Fransella, 2013). Furthermore, richer perspectives or insights can potentially be attained by investigating propositional constructs (Cohen et al., 2007). This means that factors that are considered beneficial to the analysis of mind-sets in design learning can and should be determined for investigation. Biggs's (1993) 3P model provides a general framework to further examine students' mind-sets and learning in design. Student factors on the *presage level* comprise prior predispositions that readily exist within students. It can be argued that these predispositions involve students' mind-sets which encompass their mental inclinations and responses to situations as previously discussed in Section 2.1. Consequently, student factors that are considered specific and beneficial to learning in design are adapted into Biggs' (1993) 3P model. This 3P model is used as the conceptual framework of this thesis. In the next section, the adapted model with the relevant factors to be taken into consideration is proposed and further discussed.

2.3 A conceptual framework of mind-sets in design learning

The conceptual framework to examine mind-sets in design learning is adapted from Biggs's 3P model. Biggs's 3P model markedly consists of two-way interrelations between all factors across the three levels. However, it is not possible to empirically investigate such a complex network of interrelating factors in a research project. It is commonly agreed that students' learning can be better facilitated when their ways of learning are apprehended (Entwistle & Ramsden, 2015). Furthermore, studies have indicated that individual students have unique characteristics that hypothetically influence their adoption of learning approach (Biggs, 2012; Cruickshank, 1986; Huitt, 2003) and subsequently, their learning outcomes (Meyer et al., 1990; Zhang, 2000; Grant & Dweck, 2003; Stump et al., 2009; Rodriguez, 2009; Miron-Spektor & Beenen, 2015). In addition, positive influence on the learning outcomes of students have been shown to occur when their individual capacities are harnessed. This happens when students are encouraged to act purposively in making choices (Pym & Kapp, 2011). Therefore, student related factors on the *presage level* and their interrelations with factors on the *process* and *product levels* are exclusively investigated in this research study. Particular focus is directed to examining the student factors on the *presage level* and its inter-relations to the *process* and *product* level factors (see Figure 2.2).

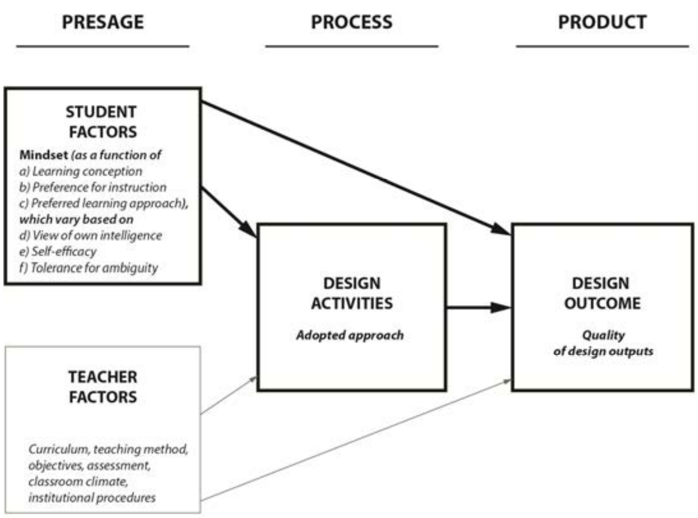

Figure 2.2 Conceptual framework of students' learning in design developed on Biggs's (1993) 3P model.

On the *presage level*, the mind-set of students in learning design is examined as a function of three variables: (1) students' learning conception; (2) their preference for instruction; and (3) their preferred learning approach. As discussed in Section 2.1, it is assumed that the notion of mind-set encompass two components. In this conceptual framework the first component of mind-set relates to students' mental inclinations with regards to learning. In this context, this is referred to as their *learning conception*. This refers to the view of or understanding and belief about learning that the student holds. Studies have empirically shown that learning conceptions are related to students' preference of learning approach (Marton & Säljö, 1976; Van Rossum et al., 1985; Purdie et al., 1996) and instruction (Entwistle, 1999). These two aspects are expected to relate to the second component of mind-set i.e., the responses that students incline toward in learning (see Section 2.1). Students' *preference for instruction* refers to the style of teaching, type of course and materials that a student would prefer to interact with. The *learning approach* that a student prefers to adopt refers to the level of processing that they expect to apply when engaged in learning activities e.g. deep or surface levels of processing (see Section 2.3.1.2) (Marton & Säaljö, 1976; Schmeck et al., 1991; Entwistle, 2001; Entwistle & Ramsden, 2015; Orsmond & Merry, 2015; Islam, 2016).

Findings from other studies suggest that there are other aspects that influence the approach that students adopt in learning. These aspects are therefore also examined on the presage level, in the investigation of mind-sets in design learning. How students view their own intelligence (more commonly referred to as self-implicit theory, see Burnette et al., 2013 and Dweck et al., 1995) has been found to relate to the approach that they choose to adopt in learning (Dahl et al., 2005; Stump et al., 2009; Yan et al., 2014). Additionally, an individual's perceived self-efficacy (which pertains to a student's evaluation of his or her capability to accomplish a task successfully, see Pintrich & de Groot, 1990) is expected to have explanatory power to clarify their behaviour mechanisms in coping with complex situations (Bandura, 1982) and influence their creative performance (Brockhus et. al 2014). This means that perceived self-efficacy is expected to relate to the learning approaches students adopt on the *process level* and outcomes on the *product level*. Furthermore, an individual's tolerance for ambiguity has been found to mediate an individual's level of self-efficacy (Lane & Klenke, 2004). Taking these findings into consideration, I propose to examine these three additional factors on the *presage level* of this conceptual framework. These include: (1) students' view of their own intelligence; (2) their perceived self-efficacy; and (3) their level of tolerance for ambiguity.

Students' level of engagement and depth of processing in design tasks are examined on the *process level*. Other studies have used qualitative methods to examine the factors situated within this level. For example, Marton & Säaljö (1976) examined the responses that students gave on different types of questions after some reading assignments. Chin & Brown (2000) observed the approaches that students adopted in learning science and Hay (2007) analysed concept maps made by postgraduate students before and after their Research Methods course. Notably, the two more current studies found that students' approaches towards learning personifies the deep and surface learning approaches as propagated by Marton & Säaljö (1976) and Entwistle (1999). These studies strongly suggest that the activities that students partake in during their learning activities can be categorised in high (deep) or low (surface) levels of engagement. In examining process related factors encompassing students' learning in design, I propose to examine the responses that students make or the activities that they undertake when engaged in a design task. These factors will be further discussed in Sections 2.3.2 and 2.3.3.

On the *product level* of this conceptual framework, outcomes that are produced by design students are assessed. The outcomes produced by students have been measured in terms of creativity in several studies (Goldschmidt & Smolkov, 2006; Goldschmidt & Sever, 2011; Sarkar & Chakrabarti, 2011; Chulvi et al., 2012; Chang et al., 2016). Some researchers assess the creativity of tangible outputs such as ideas (Dean et al., 2006; Verhaegen et al., 2013) and finished products (Sarkar & Chakrabarti, 2011). Other researchers assess the creativity of idea generation processes (Hernandez et al., 2010; Shah et al., 2000; Shah, 2003). The investigation of idea generation processes require controlled experiments which are "time-consuming, inherently subjective, [and encompasses] external validity [that] is highly uncertain when extrapolating the results to more complex engineering problems." (Verhaegen et al., 2013, p. 243). As a result, more extensive examination of design outputs have been conducted as opposed to design processes (Verhaegen et al., 2013). In the conceptual framework of this thesis, the assessment of outcomes produced by design students is focussed upon the outputs that they produce such as their design ideas.

Distinctive variables have been proposed in this adapted conceptual framework. The six variables situated within the *presage level* of the conceptual framework primarily enables the investigation of students' mind-sets specifically in a design learning setting. These variables are expected to influence the learning activities that students engage in and on the quality of design outputs that they produce. This relates to the *process* and *product levels* of the conceptual framework, respectively. Furthermore, direct interaction between variables within the *process* and *product levels* of the conceptual framework are also expected to occur. The interactions that are expected to occur between the three levels of the conceptual model are further discussed in the following sub-sections.

2.3.1 Presage level variables

Mind-sets in design learning are examined through six variables situated within the *presage level*. These variables include (1) students' learning conception; (2) their preference for instruction; (3) their preferred learning approach; (4) students' view of their own intelligence; (5) their perceived self-efficacy; and (6) their level of tolerance for ambiguity. The interactions between these variables are expected to provide insights toward the design learning mind-sets that prevail within design students.

2.3.1.1 Learning conceptions

Learning conceptions are examined through how knowledge structures are perceived and how learning processes are perceived (see Chiou et al., 2012; Marton & Säaljö, 1976; Purdie & Hattie, 2002; Rossum & Schenk, 1984; Tynjälä, 1997) (see also Table 2.1). Learning conceptions are shaped by students' anticipation of performance that is required of them (Anderson, 1970; McKenzie, 1973). Learning conceptions are related to the perception that students have towards knowledge structures, which is as something to be reproduced (surface conception) or transformed (deep conception). The deep and surface learning conceptions are similarly examined by Marton & Säaljö, (1976), Rossum & Schenk (1984), Purdie et al. (1996) and Purdie & Hattie (2002). On the other hand, Tynjälä (1997) examines conceptions related to learning processes and categorizes the conceptions as: (1) an externally determined event or process; (2) a developmental process; (3) a student activity; (4) the various strategies /styles /approaches that one adopts in learning; (5) the processing of information; (6) an interactive process; and (7) a creative process.

The surface-reproducing learning conception is related to perceiving learning as something static, where knowledge is only to be memorized, applied and increased (Marton & Säaljö, 1976; Van Rossum et al., 1985). It also encompasses viewing learning as a *duty* that needs to be performed or fulfilled (Purdie & Hattie, 2002; Purdie et al., 1996). In contrast, the deep-transforming learning conception is related to viewing learning as an activity that requires active abstraction and interpretation of knowledge, in order to acquire meaning (Marton & Säaljö, 1976; Purdie et al., 1996; Van Rossum et al., 1985). The deep-transforming conception of learning is also related to perceiving learning as an individual's own development on a personal level (Van Rossum et al., 1985; Purdie & Hattie, 2002; Purdie et al., 1996). This conception of learning also relates to viewing learning as a development of social competence and a process that is not bounded by time and context (Purdie & Hattie, 2002; Purdie et al., 1996).

Table 2.1 Learning conceptions as examined in different studies.

Category	Sub- categories	Marton and Säaljö (1979)	Van Rossum et al. (1985)	Purdie et al. (1996)	Purdie & Hattie (2002)	Tynjälä (1997)
Learning Conception						
Reproducing	Increase of knowledge	x	x	x	x	-
	Memorizing	x	x	x	x	-
	Application of information	x	x	-	-	-
	A means to an end		-	x	-	-
	A duty	-	-	x	x	-
Transforming	Abstraction of meaning	x	-	-	-	-
	Understanding reality through interpretation	x	x	x	-	-
	Personal development	-	x	x	x	X
	Seeing something in a different way	-	-	x	-	-
	A process not bound by time or context	-	-	x	x	X
	Developing social competence	-	-	x	x	-

2.3.1.2 Learning approaches

Researchers have developed questionnaires (Biggs et al., 2001; Entwistle, 1999), observed learning activities (Chin & Brown, 2000) and empirically analysed the changes in students' knowledge structure (Hay, 2007) to examine learning approaches. They commonly categorise learning approaches into two types: *deep* and *surface learning approach*. See

Table 2.2 for detailed descriptions of how different researchers describe the deep and surface learning approaches. The *deep learning approach* arises from students' interest to seek comprehension. This leads them to actively engage in linking, integrating and questioning concepts meaningfully; look for patterns and underlying principles; and examine logic and argument critically (Marton & Säaljö, 1976; Dolmans et al., 2015; Jackson, 2012).

Table 2.2 Scales for deep and surface learning approaches as measured or described in different studies.

Learning approach	Scale or Description	Source	Instrument/Method
Deep	Seeks meaning, relates ideas, uses evidence, interest in ideas, monitors effectiveness.	Entwistle (1999)	Approaches and Study Skills Inventory for Students, ASSIST
	Intrinsic interest, maximises meaning	Biggs et al. (2001)	Revised Two-factor Study Process Questionnaire,R-SPQ-2F
	Ventures ideas spontaneously; questions explanations, causes, predictions and resolved discrepancies in knowledge; engages in interactive theorizing; explains cause-effect relationships; refers to personal experience	Chin & Brown (2000)	Observation of laboratory activities and interviews
	Shows newly learnt concepts and original conceptions; links new knowledge to prior knowledge in meaningfully; improves overall knowledge structure (i.e. organisation, linkages and meaning explication).	Hay (2007)	Comparison of students' before and after concept maps
Surface	Lack of purpose, unrelated memorising, fear of failure, syllabus-boundedness	Entwistle (1999)	Approaches and Study Skills Inventory for Students, ASSIST
	Motive: Fear of failure Strategy: Narrow target, rote-learning	Biggs et al. (2001)	Revised Two-factor Study Process Questionnaire,R-SPQ-2F
	Reformulates questions and provides obvious descriptions as explanations, questions basic factual or procedural information, insufficient reflection, rigid adherence to instruction	Chin & Brown (2000)	Observation of laboratory activities and interviews
	Introduces significant numbers of new concepts that are not integrated with prior knowledge, creates new concepts that do not increase conceptual linkage of map as a whole, shows no improvements in terms of structural linkages or explanatory power.	Hay (2007)	Comparison of students' before and after concept maps

Students projecting the deep learning approach have been found to ask relevant questions on reasoning, causes, and speculation; resolve incongruities; provide elaborate explanations with cause-effect relationships; and theorize at conceptual and analytical levels (Chin & Brown, 2000). The *deep learning* approach has been described as "... an increase in structural complexity (networking), and the meaningful integration of newly acquired knowledge with the pre-existing knowledge structures." (Hay, 2007, p. 52). However, even though deeper levels of processing are demanded from students, it might not be elicited from students when they do not apprehend the deeper processing approaches that are required (Marton & Säaljö, 1976).

When students anticipate that they are required to recall factual information or reproduce lists, even though menial, they would be inclined to adopt a *surface learning approach* (Marton & Säaljö, 1976). This learning approach is associated to students' fear of failure and intention to cope with course requirements. In these situations, students memorise facts and procedures in a routine manner, study without reflection on purpose or strategy, and feel undue pressure and worry about work (Entwistle & Marton, 1989; Biggs et al., 2001; Jackson, 2012). Students inclining toward this learning approach have been found to provide reformulated questions as explanations; make observations that are focussed on physical phenomena; and rarely reflected on their own performance and new processes or information encountered (Chin & Brown, 2000).

Less commonly discussed, but nevertheless can be found in literature is the *strategic learning approach*. This learning approach is driven by students' intention to obtain highest possible grades. Students adopting this learning approach tend to be aware of assessment demands; effectively manage their resources and rely on organised studying to fulfil anticipated demands (Biggs et al., 2001; Entwistle, 1999). Additionally, researchers have also discussed combinatory learning approaches that students might be inclined to adopt. For example, the "deep-surface" learning approach is related to students attaining incomplete understanding (Entwistle, 2001).This is caused by students' inadequacy to give sufficient attention to details and the tendency to generalise and reach conclusions too quickly. It can however, equally be caused by students' unsuccessful use of analogies or personal experiences, and inability to link interconnected ideas (Entwistle, 2001, p. 597).

2.3.1.3 Preference for instruction

Preference for instruction refers not only to the style of teaching, but also the type of course and materials that a student prefers to interact with. Preferences of students may orient toward a dependency on teacher and content or on independent learning (Entwistle, 1999; Hativa & Birenbaum, 2000; Van Rossum et al., 1985) (see Table 2.3). Students inclining towards *teacher-content oriented* instruction favour the transmission of information. This includes attaining information from a clear and interesting teacher (Hativa & Birenbaum, 2000) or any forms of technology (Van Rossum et al., 1985).

Table 2.3 Categories and sub-categories of students' preference for instruction as measured or described in different studies.

<table>
<tr><th colspan="2">Preference for Instruction</th><th colspan="3">Researcher(s)</th></tr>
<tr><td>Category</td><td>Sub-categories</td><td>Van Rossum et al. (1985)</td><td>Entwistle (1999)</td><td>Hativa & Birenbaum (2000)</td></tr>
<tr><td rowspan="2">Teacher-content oriented</td><td>Transmitting information/content</td><td>x</td><td>x</td><td>X</td></tr>
<tr><td>Depending on teacher</td><td>x</td><td>-</td><td>X</td></tr>
<tr><td rowspan="2">Student-learning oriented</td><td>Facilitating understanding and/or personal development</td><td>x</td><td>x</td><td>-</td></tr>
<tr><td>Orienting student centeredness</td><td>x</td><td>-</td><td>X</td></tr>
</table>

Students that prefer independent *student-learning* incline toward teachers who support them to attain understanding (Entwistle, 1999) and promote self-regulation (Hativa & Birenbaum, 2000). These students favour increased independence and opportunities for constructive activity (Van Rossum et al., 1985). They also favour teachers that actively support their learning process (Hativa & Birenbaum, 2000) and engage in teacher-student dialogues (Van Rossum et al., 1985).

Relatively small differences can be found between the *preferences for instruction* of students from different study disciplines. For example, both engineering and education students showed preference for *teacher-content oriented* instruction (Hativa & Birenbaum, 2000). Primarily, this means that although *preferences for instruction* of design students is not expected to differ from other disciplines, differences within the students themselves are plausible. Secondarily, this indicates that students' *preference for instruction* are inconsistent with the recommendation of educational researchers, where independent learning is considered essential for 21st century learning (Stephenson & Yorke, 2013).

The three variables discussed in Sections 2.3.1.1 to 2.3.1.3 provide a basis for examining mind-sets in design learning. Mind-sets in design learning are hypothesized to encompass two components: internal mental dispositions and external behavioural responses (see Section 1). The internal aspect of mind-set can be examined through the learning conception that a student holds. The external aspect of mind-sets can be examined through the type of instruction and learning approach that students would prefer. The Approaches and Study Skills Inventory for Students (ASSIST) Questionnaire is used to assess these three variables on the *presage level* (Entwistle, 1999). The ASSIST questionnaire was most highly recommended by "researchers and experts in the field of cognitive and/or learning styles", to assess the way individuals approach learning in education or training (Peterson et al., 2009 p. 519).

2.3.1.4 View of Own Intelligence, Self-efficacy and Tolerance for Ambiguity

The *view of own intelligence* that an individual holds (more commonly referred to as *self-implicit theory*) can be referred to either as *entity view* or *incremental view* (see Section 1). The *entity view* is related to an individual perceiving their intelligence as an in-built or natural ability. Individuals that hold this view regarding their intelligence are predicted to disengage and perform poorer when faced with challenges, but succeed and perform better when faced with easy tasks (Grant & Dweck, 2003). These individuals are expected to incline toward setting *performance goals* for themselves. *Performance goals* are also known as ego-oriented goals (Miller et al., 1996). These goals are associated to an individual's pursuit of favourable judgements or avoidance of negative judgements regarding their competence (Dweck, 1986). In other words, there is a tendency for these individuals to seek validation from others regarding their abilities.

The *incremental view* is related to an individual perceiving his/her intelligence as developable through effort (Miller et al., 1996; Bråten & Olaussen, 1998; Ablard, 2002; Dupeyrat & Mariné, 2005). These individuals are expected to incline toward pursuing learning goals, which are also referred to as *task-oriented goals* or *mastery goals* (Miller et al., 1996). These goals are associated to an individual's tendency to actively seek improving his/her own skills, knowledge or competence; and developing deeper levels of understanding or mastering new situations (Dweck, 1986; Miller et al., 1996; Dupeyrat & Mariné, 2005). Students face better possibility of coping with adverse conditions and sustaining their own motivation when they set their own learning goals (Grant & Dweck, 2003). However, a study reported that the predicted effects of an individuals' *view of own intelligence* on their *goal orientations* could not be observed (Dupeyrat & Mariné, 2005).

Studies associated to self-implicit theories, goal orientations, and learning approaches have also been examined in conjunction with self-efficacy (Bråten & Olaussen, 1998; Miller et al., 1996; Pintrich & de Groot, 1990; Stump et al., 2009). Self-efficacy pertains to a student's evaluation of his or her capability to accomplish a task successfully (Pintrich & de Groot, 1990). High self-efficacy has been found to be related to positive (deep) learning approaches, (Miller et al., 1996; Pintrich & de

Groot, 1990; Rodriguez, 2009; Stump et al., 2009; Zare-ee, 2010) and higher achievement scores (Grant & Dweck, 2003; Miller et al., 1996; Pintrich & de Groot, 1990). However, students who underestimate their own performance have also been found to produce better outcomes i.e., attain better results in their studies. Christensen et al. (2002) attributes this to students' pessimism in contrast to optimism of their own outcomes, that resulted in self-regulatory behaviour which improved their performance. These contradicting findings suggest that the interpretation of self-efficacy levels to performance or achievements are also dependent on other factors in learning situations.

Performance achievements are not only influenced by an individual's level of self-efficacy, but are moreover mediated by an individual's tolerance for ambiguity (Lane & Klenke, 2004). For example, as the complexity of a task increases, an individual's tolerance for ambiguity has been found to influence the formation of their self-efficacy (Foo & Teoh, 1997). Additionally, individuals that indicate a higher tolerance for ambiguity have been found to convey higher self-efficacy levels, compared to individuals that indicate a lower tolerance for ambiguity (Endres, Chowdhury, Milner, Endres, & Chowdhury, 2015).

Tolerance for ambiguity has been defined as *"...the tendency to perceive ambiguous situations as desirable* (Budner, 1962, p. 29)". This definition was expanded and follows as *"... a range, from rejection to attraction, of reactions to stimuli perceived as unfamiliar, complex, dynamically uncertain, or subject to multiple conflicting interpretations* (McLain, 1993, p. 184)". Viewing it from an opposite angle, intolerance of ambiguity has been defined as *"...a tendency to perceive or interpret information marked by vague, incomplete, fragmented, multiple, probable, unstructured, uncertain, inconsistent, contrary, contradictory, or unclear meanings as actual or potential sources of psychological discomfort or threat* (Norton, 1975, p. 608)". These definitions commonly suggest that it is the perception of the individual with regards to the ambiguity of the stimuli which is salient, as compared to the actual ambiguity of the stimuli. Furthermore, it is an individual's perception of the stimuli that he/she encounters, that also plays a role in influencing his/her reactions.

An individual's inflexibility and tendency to "cling to familiar and precise details" (Frenkel-Brunswik, 1949, p. 141) relates to the tendency to ignore other aspects related to a situation. In turn, this results in a haphazard approach towards reality (Frenkel-Brunswik, 1949). Building on this description and the previous findings, it can be assumed that inflexibility of interpretations related to complex problem solving situations, results in potentially unsystematic design decisions and rationales for design decisions. Students with a low tolerance for ambiguity are stipulated to react aversively in ambiguous situations due to difficulty in accessing risk and making decisions correctly (Furnham & Ribchester, 1995). Furthermore, students with low tolerance for ambiguity have been reported to show signs of anxiety, evasion, deferring putting an end to things and also rejection (Furnham & Marks, 2013). In contrast, students that are highly tolerant towards ambiguity perceive ambiguous situations as "desirable, challenging and interesting" (Furnham & Marks, 2013, p. 718).

2.3.2 Process and product level variables

Various aspects influence the creativity of design ideas. The manner or way in which students engage in their design tasks are expected to influence the outcomes that they produce. For example, the use of different learning activities (Groenendijk et al., 2013) and different design methods or tools and result in different levels of creativity (Cubukcu & Cetintahra, 2010; Goldschmidt & Sever, 2009, 2011; Goldschmidt & Smolkov, 2006; Gonçalves et al., 2013). By using more creativity tools (e.g. such as analogies, brainstorming, mind-mapping) and by sustaining efforts to generate ideas towards the end of a design project, a variety of unique design ideas can be generated (Bourgeois-Bougrine et al., 2017). Design ideas are also influenced by the active reflection or unreflective inquiry that a student undertakes in relation to the problem space of a design problem (Christensen et al., 2016). Taking these aspects into consideration, focus is directed toward examining the engagement of students in their design tasks in terms of their question–asking tendencies, comprehensiveness of considerations and design activities related to the design task at hand. These aspects are expected to influence the design outputs that are produced by students.

Design outputs have been assessed for the level of creativity. Concurrence on methods of measuring creativity, although not conclusive, have been attempted (Gonçalves, 2016). For example, quality measures from *Decision Support Systems* (DSS) research have been used to consolidate criteria for evaluating creative outputs (MacCrimmon & Wagner, 1994). The criteria recommended consists of five different scales that include novelty, non-obviousness, workability, relevance and thoroughness. These scales were then further developed when the *novelty*, *quality* and *creativity* of ideas were separately defined (Dean et al., 2006).

A *novel idea* was defined as "...rare, unusual or uncommon...[where it can be] judged in relation to how uncommon it is in the mind of the idea rater or how uncommon it is in the overall population of ideas (Dean et al., 2006, p. 648)". On the other hand, a *quality idea* was defined as an idea that applies to the problem at hand, is an effective and also implementable solution. Finally, a *creative idea* is defined as one that satisfies both novel and quality idea criteria. A *creative idea* fulfils four characteristics: (1) is *novel* and also fulfils three different dimensions of quality: (2) *workability*; (3) *relevance*; and (4) *specificity*.

The *novelty* of an idea can be measured through two sub-dimensions: *originality* and *paradigm relatedness* (Dean et al., 2006; Verhaegen et al., 2013). The former relates to the degree to which an idea is not only rare but is also ingenious, imaginative or surprising. The latter refers to the degree to which an idea preserves a paradigm i.e., adapts similar elements of a paradigm, or modifies a paradigm i.e. extends, redesigns or radically transforms elements of a paradigm. The *workability* or *usefulness* (Pluckeret al., 2004; Woodman et al., 2016) of an idea is related to how easily an idea can be implemented while not violating any known constraints. Two sub-dimensions are measured on this aspect: *acceptability* (the degree to which an idea is socially, legally, or politically acceptable) and *implementability* (the degree to which an idea can easily be implemented.

The *relevance* of an idea is related to the *applicability* and *effectiveness* of the idea to the stated problem (Dean et al., 2006; Verhaegen et al., 2013). *Applicability* refers to how clearly the idea applies to the stated problem while *effectiveness* refers to the degree to which the idea will solve the stated problem. The *specificity* of an idea refers to whether the idea has been worked out clearly and in detail. This dimension is also referred to as *thoroughness* (MacCrimmon & Wagner, 1994). *Specificity* can be measured on three sub dimensions: (1) *implicational effectiveness*; (2) *completeness*; and (3) *clarity*. *Implicational effectiveness* refers to the clarity of articulation regarding the relationship between the recommended action and expected outcome. *Completeness* refers to the number of sub components and breadth of coverage that an idea can be decomposed into. *Clarity* refers to how clearly an idea is communicated with regard to grammar and word usage.

Creativity scales are commonly used in varying and non-uniform ways leading to inconsistent and incomparable findings (Dean et al., 2006). The generality or specificity of contexts that are introduced in design problems also play a role in the plausibility of creativity assessment. The evaluation of quality as compared to novelty is more plausible for design problems that involve specific contexts (Gonçalves, 2016). Keeping these aspects in mind, the interpretation of novel, quality and creative ideas need to be clearly delineated. In addition, clear reporting of the appropriate scales assessed needs to be presented in order to enable comparability of findings across future studies (Dean et al., 2006).

2.3.3 Factors influencing outcomes

Deep-transforming learning conceptions are linked to better outcomes in learning (Christie, 2000; Marton & Säaljö, 1976). The learning approach that students adopt is also expected to influence their achievement (Entwistle & Ramsden, 2015). The deployment of surface learning approaches with intention to reproduce information is expected to hinder the progress of greater levels of understanding (Marton & Säaljö, 1976). However, when students adopt both surface and strategic learning approaches, it is possible that they will achieve high grades, though high grades can be achieved whether students attain understanding, or not (Entwistle, 2001). In essence, researchers suggest that low inclinations toward the surface approach (Entwistle, 1999) and high inclinations toward the deep (Christie, 2000; Grant & Dweck, 2003; Miller et al., 1996; Pintrich & de Groot, 1990; Stump et al., 2009) and strategic learning approaches (Rodriguez, 2009) contribute to better achievement. Additionally, preference for *teacher-content oriented* instruction proves unfavourable to learning (Hativa & Birenbaum, 2000). However, students' learning approaches and preferences should not necessarily be assumed as good or bad. Salient contextual factors should be taken into account during its interpretation (Dinsmore & Alexander, 2012).

The manner in which students view their own intelligence influences the approach students adopt in learning (Dahl et al., 2005; Stump et al., 2009; Yan et al., 2014). Additionally, an individuals' view of their own intelligence influences the levels of achievement that they attain (Bråten & Olaussen, 1998; Burnette et al., 2013; Huang, 2011; Yan et al., 2014). This is because the views that they hold, regarding their own intelligence, influences their proceeding behavioural responses in learning. Individuals holding the *entity* view of own intelligence are adverse toward positive i.e., deep learning approaches that include inclinations towards collaboration and knowledge building activities (Dahl et al., 2005; Stump et al., 2009). Additionally, individuals that hold an *incremental* view of their own intelligence are inherently motivated to learn and have been found to be more likely to re-study old course materials and re-visit prior information that they come across in their studies (Yan et al., 2014). *Incremental views* of one's own intelligence are related to resilience in facing challenges, resulting in higher achievement and greater course completion rates (Yeager & Dweck, 2012). This view allows for achievement to be predicted over time, particularly in difficult conditions (Dweck, 2015).This indicates that students who believe their intelligence as malleable are more likely to overcome the complexities inherent in learning design and achieve better outcomes.

Several studies indicate that high self-efficacy leads to better achievement (Grant & Dweck, 2003; Miller et al., 1996; Pintrich & de Groot, 1990). However, high self-efficacy coupled with over-optimism can also lead to the deterioration of subsequent performance (Christensen et al., 2002). Students' subsequent performance can improve when they conservatively predict their level of self-efficacy as below their achieved outcomes, that is, if they also engage in self-regulatory behaviour to improve future outcomes (Christensen et al., 2002). This suggests that careful interpretation of self-efficacy scores should be conducted, taking into account other possibly related factors. Students' evaluation of their self-efficacy should also be interpreted with context dependant factors in mind. Additionally, a high tolerance for ambiguity enables individuals to overcome barriers and to adapt, by changing plans flexibly in problem solving activities (Binkley et al., 2012). This indicates that students' tolerance for ambiguity also plays a role in mediating their behaviour in complex design learning situations.

2.4 Conclusion

Individual differences that prevail within students play a role in influencing their approaches in learning (Entwistle & Ramsden, 2015). In this chapter, an adapted conceptual framework that includes several distinct variables is proposed to investigate and, furthermore, to test an aspect of students' individual differences: their mind-set in design learning. A more comprehensive view of students' interpretations and responses in learning design is focussed upon in order to understand: (1) the prevalent mind-sets that students have towards design learning and how they can be measured; and (2) what other factors are characteristic of these mind-set types. This will eventually contribute to the identification and testing of the collective mind-sets of students in a design learning context. Existing literature related to variables that are proposed in the adapted conceptual framework were reviewed and discussed. This review provides some fundamental guidelines for the investigation and testing of mind-sets in design learning in the following studies of this thesis.

Firstly, certain patterns of interactions within variables on the presage level can be expected. For example, the conceptions that a student holds regarding learning is related to the learning approach that they would prefer to adopt (Dinsmore & Alexander, 2012; Entwistle & Ramsden, 2015; Sadler-Smith, 2010). Students holding surface learning conceptions are more likely to adopt surface learning approaches, while students with deep learning conceptions are more likely to incline towards deep learning approaches (Rossum & Schenk, 1984; Dart et al., 2000; Purdie & Hattie, 2002; Chiou et al., 2012). Additionally, these learning conceptions and approaches are connected to the type of instructions that students would prefer to engage with throughout their learning. Students who adopt different approaches toward learning are inclined to prefer different types of instruction, favouring instruction that fulfils their particular needs in learning (Hativa & Birenbaum, 2000). Students that incline toward the deep learning approach will prefer teachers that will facilitate their personal development and understanding, while students that incline toward the surface learning approach will prefer instruction that focusses on the transmission of information (Entwistle, 1999; Entwistle & Smith, 2002).

Secondly, the view that students hold regarding their own intelligence are related to their adoption of distinct learning approaches, which in turn influences the quality of their outcomes (Bråten & Olaussen, 1998; Dweck, 2015; Zeng, Hou, & Peng, 2016).

When students view their own intelligence as a malleable trait i.e., *incremental view* they are more likely to incline toward deep learning approaches. On the other hand, when they view their own intelligence as a fixed and unchangeable trait i.e., *entity view* they are more likely to incline toward the surface learning approach (Bråten & Olaussen, 1998; Mangels et al., 2006; Yeager & Dweck, 2012). Students who are pessimistic of their own performance i.e., perceive that their self-efficacy is lower compared to their actual performance, adopt positive regulatory behaviour in learning that is characteristic of the deep learning approach (Christensen et al., 2002). These students are expected to have lower tolerance for ambiguity as individuals that have a higher tolerance for ambiguity show higher self-efficacy levels, compared to individuals' that have lower tolerance for ambiguity (Endres et al., 2015). Individuals with low tolerance for ambiguity are expected to avoid ambiguous situations (Furnham & Ribchester, 1995). In design learning, the manner in which students react, in their attempt to avoid ambiguity, will play a big role to the success of their learning. It can be conjectured that one can avoid ambiguity by evading or clarifying the situation, and it is this response that influences the activities that students engage in throughout their learning.

The perceptions that students have, regarding learning and their own intelligence and capabilities, influences their preferences and behavioural responses in learning situations. The interactions between these variables, on the *presage level*, are expected to facilitate the investigation of mind-sets that prevail within students in design learning. In turn these individual differences are expected to influence the behavioural responses and quality of outcomes produced by students. In the following chapters, three studies that examine different parts of the adapted conceptual framework are presented.

In Chapter 3, the first study examines three variables of the *student factors* on the *presage level.* These variables relate to the learning conception, preferred learning approaches and preference for instruction of design students. Based on the findings of this study, two distinct *design learning mind-set* categories are developed and presented in this chapter. In Chapter 4, all variables in the *student factors* of the *presage level* and its relation to outcomes on the *product level* that was investigated in the second study are presented. Further findings to describe the characteristics of the different mind–sets are discussed. In Chapter 5, variables on all three levels of the conceptual framework that is examined in the third study are presented. Compelling findings related to the characterization of the different mind-set types and its influence on outcomes on the *product level* are discussed. At the outset, how can mind-sets in design learning be described? This is investigated and discussed in the following chapter.

3

Discerning and opportunistic mind-sets in design learning

In the previous chapter, factors underlying mind-sets in design learning were presented. To examine these ideas, three variables within the presage level of Biggs' 3P model (as discussed in Section 2.3) are examined in this chapter. The three variables pertain to student-related factors. They encompass students' learning conception (the internal aspect of mind-set); and preference for instruction and preferred learning approach (the external aspects of mind-set). Data was collected using the ASSIST Questionnaire (Entwistle et al., 1997) and semi-structured interviews. Qualitative findings from the semi-structured interviews were used to provide further insights and complement results yielded from the quantitative data. Based on the results, two categories of mind-sets in design learning are proposed: the discerning and opportunistic mind-sets. Distinguishing characteristics related to the two mind-sets are presented.

3.1 Research aims, hypotheses and questions

Following the discussions in the previous chapter, the prime interest of this research lies in examining the nature of mind-sets of design students that influence their learning in design. Thus, the main research question considered in this study is framed as follows:

What is the nature of mind-sets in design students?

It is expected that the nature of mind-set in design students can be examined by firstly exploring their learning conceptions, which are related to their mental state i.e., an internal aspect of their mind-set. This mental state, in turn, determines the responses that they bring forth in their design learning activities. It is assumed that their learning conceptions influence their preferences for instruction and learning approaches (the external aspects of mind-set). Therefore, the influence of students' learning conceptions on their preferences for instruction and learning approaches is also examined. These three variables lie on the presage level of Bigg's 3P model (see Figure 2.2 in Chapter 2).

Learning conceptions are related to how students perceive knowledge structures (see Chiou et al., 2012; Marton & Säaljö, 1976; Purdie & Hattie, 2002; Rossum & Schenk, 1984). Knowledge structures can be perceived as something to be reproduced (surface-reproducing conception) or transformed (deep-transforming conception) (Marton & Säaljö, 1976; Rossum & Schenk, 1984; Purdie et al., 1996; Purdie & Hattie, 2002). *Preference for instruction* refers to the style of teaching and the type of course and materials that a student would prefer to interact with. On the two extremes, it is expected that design students that incline toward the opportunistic mind-set will favour teachers and course material that emphasizes the transmission of information, while students that incline toward the discerning mind-set are concerned with developing their personal understanding (Entwistle, 1999; Hativa & Birenbaum, 2000; Van Rossum et al., 1985). *Learning approaches* refer to the "level of engagement or depth of processing [that a student applies] during learning" (Cassidy, 2004, p. 433).

Learning approaches can be categorised into deep, surface and strategic learning approaches. The deep learning approach is related to actively engaging in linking, integrating and questioning concepts meaningfully; looking for patterns and underlying principles; and examining logic and argument critically (Marton & Säaljö, 1976; Dolmans et al., 2015; Jackson, 2012). The surface learning approach is related to students' fear of failure and intention to cope with course requirements. In these situations, students memorise facts and procedures in a routine manner, study without reflection on purpose or strategy, and feel undue pressure and worry about work (Entwistle & Marton, 1989; Biggs et al., 2001; Jackson, 2012). The strategic learning approach is related to students' intention to obtain the highest possible grades. Students adopting this learning approach tend to be aware of assessment demands, effectively manage their resources and rely on organised studying to fulfil anticipated demands (Biggs et al., 2001; Entwistle, 1999).

It is expected that when students hold a surface conception toward learning, they will incline toward instruction that emphasizes the transmission of information, and they will prefer a surface approach toward learning such as memorising facts and information. It is also expected that when students hold a deep conception toward learning, they will incline toward instruction that emphasizes the development of their personal understanding, and they will prefer a deep approach toward learning, such as actively seeking meaning between concepts and relating ideas. It can be expected that differences in learning conceptions will also influence design students.

To answer the main research question stated previously, and test the hypothesized relationships between these variables, the following research sub-questions will be addressed:

> *1. What are the learning conception, preference for instruction and learning approach that design students incline toward?*
>
> *2. How do the learning conceptions of design students relate to their preference for instruction and learning approach?*

3.2 Methods

The use of multi-method approaches such as combining quantitative and qualitative evidence to draw conclusions and build rationale, has been recommended in the evaluation of empirical data (Johnson & Onwuegbuzie, 2004). The use of different data sources can be used to improve the validity of the results as "independent measures of the same objective" can be converged as a check on validity (Cohen et al., 2007 p. 143). In this study, these recommendations are implemented by collecting quantitative data from the Approaches and Study Skills Inventory for Students (ASSIST) (Entwistle, 1999), and qualitative data from semi-structured interviews. The three variables assessed in the ASSIST questionnaire include students' learning conception, which encompasses the internal aspect of mind-set; and preference for instruction and preferred learning approach, encompassing the external aspects of mind-set. The quantitative data, derived from the ASSIST questionnaire, forms the main data point of this study. It provides an indication of the mind-sets that design students adopt in design learning. The qualitative data derived from the semi-structured interviews was collected as an additional measure to validate the quantitative data.

3.2.1 Participants

The main purpose of this study was to identify the mind-sets of students that are involved in design learning. Thus, considerable emphasis was given to collecting data from students that were enrolled in design courses. The ASSIST questionnaire was distributed to 191 undergraduate students from industrial, product and automotive design courses. Responses from all 191 participants were received. 146 of the students were from three different universities in Malaysia while 45 of them were from a university in the Netherlands. 106 of the participants were male, 81 were female, and four participants did not report their gender. The age of participants ranged between 18 to 25 years old (M=21.67, SD=1.48).

The semi-structured interviews were conducted with 12 out of the 191 participants from two of the universities in Malaysia. The design programmes of these two universities differ from one another, where one is a technical design programme while the other focusses on the arts. Six participants were interviewed from each university, with three participants in their first year and the other three in the final year of their studies. Four of the participants were male while the remaining eight were female. The participants were selected using the "selective sampling" technique where respondents are selected based on prior rational criteria (Coyne, 1997). These criteria relate to the difference in years of study and how participants currently performed in their class. Participants who had low, mediocre and high performance from each year were selected based on recommendations from their teachers. The range of students are expected to provide a more generalizable range of insights to the learning conceptions, preference for instruction and learning approaches of the design students.

3.2.2 Quantitative data

Data collected using the ASSIST consists of 66-items, assessed on a 5-point Likert scale, that were used in its original form. This was done to preserve the validity and reliability of the instrument (Korb, 2013). These items assess three variables related to participants' learning conception (6 items), participants' preference for instruction (8 items), and their preferred learning approach (52 items) (see Appendix A).

To examine the learning conception, preference for instruction and learning approach that design students incline toward (RQ1) and how these variables relate to the design learning mind-set of students (RQ 2), these variables are first examined using separate *Principal-component analyses* with *Varimax rotation* (Field, 2013). This analysis was conducted to identify the structure of the learning conceptions, preferences of instruction and preferred learning approaches variables as indicated by the design students (Field, 2013). Next, the resulting scales for the three variables are tested using Cronbach's Alpha, α to test the reliability of the items within each scale (see Appendix B).

Items were removed from the learning approach scales to increase its internal reliability (Field, 2013). In other words, only items that "consistently reflect[s] the construct that it is measuring" are retained (Field, 2013, p. 706). The reliability of the three *learning approach* scales (*deep, strategic* and *surface*) and the *deep-transforming learning conception* scales range from marginally to highly reliable values with Cronbach's *α*, ranged from 0.60 to 0.79. The remaining *preference for instruction* scales (*transmitting information* and *supporting understanding*) and *surface-reproducing learning conception* scales yielded reliability values of just under 0.60. These values indicate lower reliability scores. Although this shows that the related items are less closely linked as a group, the value of Cronbach's *α* is also dependent on the number of items in the scales (Field, 2013). On the whole, although higher *α*-

values would have been preferred, the scales are used in the subsequent analysis, due to the given circumstances. In light of the moderately low α-values, and as an additional measure of validity, items in each scale were carefully scrutinised and discussed for logical consistency with two other research experts with more than 30 years of experience in the field of research in psychology and design. See Appendix B for the Cronbach's alpha of each scale, its original number of items and the final number of items retained.

Items in each scale were next computed for further analysis. To examine how these variables relate to each other, the correlations between these scales were tested using Spearman's correlational analysis (Field, 2013). Through this test, the author assumes that she can examine what these relations mean for the design learning mind-set of students, as hypothesized in Section 3, and assumed in Section 2.3.1.

As indicated in Section 2.3.1.3, it is assumed that the internal aspect of mind-sets can be examined through the learning conception that a student holds, while the external aspect of mind-sets can be examined through the type of instruction and learning approach that students would prefer. To test this assumption, participants were first clustered according to their responses on the deep learning conception scale (*M*=4.05 , *SD*=0.71, *Median*=4.33). Participants that indicated scores above the median value were grouped as belonging to a high-deep learning conception (high DTLC) cluster (*M*=4.57, *SD*=0.29). Participants that indicated scores below the median value were grouped to belong to a low-deep learning conception (low DTLC) cluster (*M*=3.52, *SD*=0.61). Next, these two clusters were compared to the external aspects of mind-sets i.e., their preferences for instruction and preferred learning approaches.

Results yielded from the questionnaire forms the quantitative data used to interpret mind-sets in design learning. In addition to the quantitative data, qualitative findings from the semi-structured interviews are used to validate the quantitative findings. Transcriptions from the semi-structured interviews were used to cross-validate the quantitative results and enabled a systematic description of the mind-set categories in design learning. This was done using the thematic coding method of analysis (Miles, Huberman, & Saldana, 1994; Saldana, 2009). Details of the qualitative data collection and analysis are discussed in the following section.

3.2.3 Qualitative data

An interview guideline was prepared for the semi-structured interviews. This was done to ensure that the "same basic lines of inquiry" could be conducted for each participant interviewed (Patton, 2002, p. 343) (see Appendix C for the interview guideline). Questions in the interview guideline were asked to provide further insights on participants' responses on the ASSIST questionnaire. Questions were formulated to include learning situations such as their design studio-based courses and courses related to other subjects. Questions were sequenced to inquire firstly, about participants' present and subsequently, about their past learning experiences. This assists the transition from simpler to more difficult questions as it is easier for respondents to answer questions that are related to the present, compared to the past (Patton, 2002, p. 353). Additionally, questions were kept open-ended. Leading questions were avoided to encourage participants to candidly describe their experiences. Probing questions were also included to assist in obtaining clarification and more in-depth information (Charmaz, 2006b). Participants were given the freedom to talk about situations in any other courses that contributed to their learning in a meaningful way. This enables observable behaviours as well as interpretive responses of the participants' to be drawn (Patton, 2002).

The interview audios amounted to a total of 778 minutes and were fully transcribed on a verbatim basis. The transcriptions of the semi-structured interviews form substantial verbatim material that provide a solid basis to corroborate claims related to mind-sets in design learning (Charmaz, 2006a). Additionally, it allows for thorough search and recognition of each participant's points of view, and also for comparisons between participants (see Patton, 2002). The transcriptions were examined in two cycles of coding. Codes in the first and second cycle were made by the author and subsequently cross-checked by an expert with approximately 30 years of experience in the area of protocol analysis.

The first cycle of coding was conducted using the *incident-by-incident* method and *process coding* technique to assign codes to data chunks in the transcript (Saldana, 2009). 772 codes were generated in this cycle of coding. Observable and conceptual actions in the transcriptions were coded with gerunds ("-ing" words) to achieve a strong sense of action and sequence (Miles et al., 1994). This is referred to as the *process coding* technique where participants' actions and perceptions of learning in design are extracted (Charmaz, 2006b). By using this method, the activity of coding is directed by the development of ideas and information encountered throughout the transcriptions (Charmaz, 2006b, p. 51). For example, the following quotation was coded as "*extracting knowledge for personal adaptation*":

Quotation 1
I think, for my final year project, I understand what I did before because... I think... and like, I will look at other projects, and I will also listen (during critique sessions) then I can see the whole thing... then I start to understand the previous project, then I understand what I need to do (in my project)... ***(Respondent ID: 5)***

The next quotations were coded as *"executing assignments based on lecturers' dictation":*

Quotation 2
Me...? What the lecturer tells me to do, I'll do that because... that is for the future... ***(Respondent ID: 2)***

Quotation 3
This lecturer... he likes ideas that are based on 3D... so we will make lots of mock-ups... he definitely likes things in 3D compared to sketches... up to this stage, we are making actual size mock-ups... after that, only then... will proceed to make the model... when he says that its ok to... ***(Respondent ID: 10)***

In the second cycle of coding, codes generated in the *First Cycle* are amalgamated into "more meaningful and parsimonious units of analysis" which are referred to as *pattern codes* (Miles et al., 1994, p. 90). The scales of the ASSIST questionnaire were referenced in the process of creating these *pattern codes.* New pattern codes were generated when codes from the first cycle did not fit into any of the scales that were referenced from the ASSIST questionnaire. For example, some codes (e.g. *extracting knowledge for personal adaptation;* and *seeing connections between what is being done in classes and how it fits as a whole into the project itself)* were merged into a *pattern code* named *Deep learning: Relating ideas.* The code "relating ideas" is a scale of deep learning that can be found in current literature (Entwistle, 2001; Entwistle et al., 1997). On the other hand, some codes (e.g. *executing assignments based on lecturers' dictation; correcting objectives of project in a contrived manner; fulfilling lecturers' preferences*) were merged into the *pattern code* named *Surface learning: Taking convenient measures.* See Appendix D for the code list generated in the second cycle.

As a means of generating meaning, plausible interconnections that "makes good sense, and fits" within the pattern codes were firstly regarded as initial impressions (Miles et al., 1994, p. 244). These initial impressions are next verified by tallying the frequencies of the pattern codes to avoid bias (Miles et al., 1994). The interactions of pattern codes generated in the second cycle, which similarly relates to the preference for instruction and learning approach variables as in the quantitative data, were used to designate the names of the two design learning mind-sets and also describe their fundamental differences. The interactions between the pattern codes are mapped out and visualized in a *network display* (Miles et al.,1994) (See Figure 3.1).

3.3 Results

The results of this study firstly address the learning conception, preference for instruction and learning approach that design students incline toward (RQ 1). Secondly, the results address how these three variables relate to the design learning mind-set of design students (RQ 2). In doing so, both the results of the qualitative and quantitative data points are taken into account. This is especially so for students' preference for instruction and learning approaches, but not for their learning conception. Results related to students' learning conception are derived only from the main quantitative data point, as data from the semi-structured interviews were not available.

3.3.1 Learning conception (RQ 1)

From literature, *learning conceptions* are assessed on two scales: the *deep-transforming* or *surface-reproducing* scale (see Section 2.3.1.1). The *deep-transforming* scale is related to perceiving knowledge structures as something to be transformed, while the *surface-reproducing* scale is related to perceiving knowledge structures as something to be reproduced (Marton & Säaljö, 1976; Rossum & Schenk, 1984; Purdie et al., 1996; Purdie & Hattie, 2002). From the principal-component analysis method with Varimax rotation, the two scales as indicated in literature could also be found in this study (see Appendix F). Five out of six of the items remained, consistent with Entwistle et al's. (1997) proposition. The five items yielded high factor loadings of above 0.40, indicating strong associations between the items that loaded on each factor. The Kaiser-Meyer-Olkin measure of sampling adequacy was above 0.6 at KMO=.64. The five items loaded onto two factors that account for 35.04% and 24.09% of the total variance.

Three items loaded on Factor 1 are related to the *deep-transforming learning conception* (M=4.05 , SD=0.71). The three items include: (1) Seeing things in a different and more meaningful way ; (2) Understanding new material for yourself ; and (3) Developing as a person. The two items that loaded onto Factor 2 are related to the *surface-reproducing learning conception* (M=3.87, SD=0.68). The two items include: (1) Making sure you remember things well; and (2) Building up knowledge by acquiring facts and information. As only two items were clustered onto Factor 2, a Spearman's correlational analysis was also conducted to verify the relation between the two items. This analysis indicates that the two items were significantly and positively correlated to one another, $r(190)=.19$, $p=.009$. This means that as students indicated higher agreement toward the notion that knowledge is related to making sure that they remember things well, they also indicated higher agreement toward the notion that knowledge is built up by acquiring facts and information.

3.3.2 Preference for Instruction (RQ 1)

From the literature, *preference for instruction* is assessed on the *supporting understanding* (PFI: U) or *transmitting information* (PFI: I) scales (see Section 2.3.1.3). From the principal-component analysis method with Varimax rotation, the two scales as indicated in literature could also be found in this study (see Appendix G). The eight items yielded high factor loadings of above 0.40, indicating strong associations between the items that loaded on each factor. The Kaiser-Meyer-Olkin measure of sampling adequacy was above 0.6 at KMO=.63. The five items loaded onto two factors that account for 23.77% and 19.61% of the total variance.

Four items loaded on Factor 1 are related to preference for instruction that focusses on transmission of information (M=3.57, SD=0.88). The four items include: (1) Courses in which it's made very clear just which books we have to read; (2) Lecturers who tell us exactly what to put down in our notes; (3) Exams or tests which need only the material provided in our lecture notes; and (4) Books which give you definite facts and information which can easily be learned. Four items loaded on Factor 2 are related to preference for instruction that supports the development of personal understanding (M=3.87, SD=0.71). The four items include: (1) Exams which allow me to show that I've thought about the course material for myself.; (2) Books which challenge you and provide explanations which go beyond the lectures.; (3) Lecturers who encourage us to think for ourselves and show us how they themselves think; and (4) Courses where we're encouraged to read around the subject a lot for ourselves.

From the second cycle coding of the qualitative data, further insight related to preferences for instruction can also be found. Participants had indicated instances where their teachers focussed on transmitting information. From these instances, it can be observed that the transmission of information may entail situations where design teachers would (1) dictate the design directions that participants should pursue in their design projects; (2) focus on tangible outcomes generated by participants; and (3) depart knowledge in an obscure way. Dictation of design directions is related to instances where the decision making-processes in designing are made by the design teachers. An example of a quotation extracted from a participant related to the pattern code *"dictating design direction"* is as follows:

Quotation 4

"...the lecturer will explain what we need to do, then we will conduct our research... once the research is complete, we will present it to the lecturer... depending on whether the lecturer likes it or not, we will design it... if the lecturer accepts everything, right... we will proceed to make the thing..."

(Respondent ID: 9)

Focus on outcomes is related to teachers placing importance on tangible outputs such as sketches, prototypes, visually interesting designs, and required formats and deliverables. An example of a quotation extracted from a participant related to the pattern code *"focus on outcome"* is as follows:

Quotation 5

" ...what the lecturer thinks is interesting... the design is interesting, the lecturer will immediately accept, if the design is not interesting, the lecturer will not accept... "
(Respondent ID: 9)

Departing knowledge in an obscure way is related to conveying knowledge in an unclear or unsystematic manner, which leads to students receiving unintegrated and separate pieces of information. An example of quotations extracted from participants related to the pattern code *"departing knowledge in an obscure way"* is as follows:

Quotation 6

"... the lecturer wants to explain something to us... but we don't get it... we're still lost... so most students are lost compared to proceeding forwards... "
(Respondent ID: 4)

Quotation 7

"...it's different with the normal subject... like I also don't know what need to be teach because... like it's not systematic like... today, we want to learn this, learn that... it's like very random, the process..."
(Respondent ID: 5)

Participants had also indicated instances where their teachers focussed on supporting their personal development and understanding. From these instances, participants indicated that they draw support from their teachers when their teachers (1) conveyed ideas coherently; (2) monitored participants' understanding throughout their course; and (3) promoted reflection in their interaction. Participants' indicated that their understanding toward a topic area increases when their teachers conveyed their ideas coherently. One such quotation that illustrates the pattern code *"conveys ideas coherently"* is as follows:

Quotation 8

"...then I learnt a lot from the critique sessions, when we discussed about my friend's project... although our projects are different, but I learn from everybody's project... there are more examples... like it's easier to understand what the design process is about... overall..."
(Respondent ID: 5)

When their teachers stopped to check whether students understood, these instances were coded as *"monitors understanding"*. An example of a quotation denoting this pattern code is as follows:

Quotation 9

"...each time before giving us the assignment, the lecturer will ask whether we understand how to go about... if we're all quiet, it means that it's the first time we've heard about it... so, when the lecturer knows that it's new for us, he will explain how we should do it..."
(Respondent ID: 11)

When their teachers propagate reflection through questioning or encouraging exploration, these instances were coded as *"monitors understanding"*. An example of a quotation denoting this pattern code is as follows: (see Appendix D for the codebook).

Quotation 10

"...for example, when I present my project, the lecturer questioned, what did I mean by small, medium or large... for the event... and what programmes were they doing on the stage... ? I didn't look into that aspect... that was one thing that helped... the lecturer suggested to look at this ,this ,this..."
(Respondent ID: 4)

3.3.3 Learning approaches (RQ 1)

From the literature, *learning approaches* are assessed on three scales: the *deep*, *strategic* and *surface* learning approaches (see Section 2.3.1.2). From the principal-component analysis method with Varimax rotation, the three scales as indicated in literature could also be found in this study. A fixed number of three factors were used to categorise the *deep*, *surface* and *strategic learning approaches* as suggested by Entwistle et al. (1997). Extraction based on eigenvalues larger than 1 were used. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO=.77. This value indicates that the three factors are distinct and reliable as it is well above the acceptable limit of .5 (Field, 2013). The three factors accounted for 12.18%, 10.99% and 10.62% of the total variance respectively (see Appendix E).

Items that loaded on Factor 1 are related to the *deep learning approach* (M=3.90, SD=0.48). These items are related to students' interest in ideas that they encounter in learning, their preference for relating ideas, seeking meaning and using evidence in their learning activities together. Additionally, items indicating students' inclination to do well in courses, monitor the effectiveness of the work that they have done, and their alertness toward assessment demands are also loaded onto Factor 1. Items that loaded on Factor 2 are related to the *strategic learning approach* (M=3.27, SD=0.78). These items are related to students' inclination to organise their studying and managing their time for study-related activities. Items that are loaded onto Factor 3 are related to the *surface learning approach* (*M*=3.26, *SD*=0.66). These items indicate participants' lack of purpose in doing the course they are enrolled in, their tendencies to engage in unrelated memorising activities, and their inclinations to be bounded by their course syllabus.

From the second cycle coding of the qualitative data, further insight related to learning approaches in design learning can be found. Deep learning approaches that participants conveyed about similarly illustrated their tendencies to be interested in ideas, to relate ideas, seek meaning and use evidence in their learning activities (as found in the quantitative data). However, apart from those aspects, that is characteristic of the deep learning approach, participants also mentioned that they would overcome or rise up to the task, when faced with challenging situations. Similar instances such as this, were regarded as a deep learning approach toward learning, and assigned as the pattern code *facing challenges* (see Quotation 11 and Quotation 12).

Quotation 11
"I will... like try and error... Try out everything possible. And then try to see whether it will... look nice in this position, this arrangement, if it's not, then I will try it in another arrangement. Because this... we need to try it on our own."
(Respondent ID:1)

Quotation 12
Hmmm.... because our lecturer is always letting us experience [things for] ourselves. He won't like.... if you want to try, he will say, go ahead... then if we make any mistakes, we can straight away learn from it. So, I don't know, I do like that kind of... like we experience our self so that we can like remember it. Really, really remember it... And to me, that's interesting...
(Respondent ID: 1)

The surface learning approach that participants mentioned in the semi –structured interviews distinctly relate to three aspects. This includes their tendencies to (1) take convenient measures; (2) use limited evidence in their design projects; and (3) perform routine actions. When participants conveyed that they would take convenient measures, this refers to their tendencies to engage in actions that would compromise deeper levels of processing in order to decrease their work load (see Quotation 13). When participants indicated that they would use limited evidence, this refers to their tendencies to utilize information or methods that are easily accessible to them, without considering imperative requirements as required by task/situation (see Quotation 14). When participants indicated their tendencies to perform routine actions, this relates to their execution of customary actions that includes memorising, executing instructions or actions with limited understanding (see Quotation 15).

Quotation 13
" ...I was doing the research on the tree....so if I changed the subject matter, I would have to conduct all of my research all over again... so I changed to [looking at] its fruit, I didn't take the branch [anymore]... I used the branch for the lighting project and the fruit for the furniture project... so I don't have too much research that I needed to do as I had already researched about the tree..."
(Respondent ID: 10)

Quotation 14
" ...I would think of my own logics, what I am fond of... I pick the living room for the family so that my own family can use it later on... besides, compared to the toilet and kitchen, users don't use the space as frequently as they do the living rooms... so there is more opportunity for me to research for problems... "
(Respondent ID: 11)

Quotation 15
" ...we will need to complete last week's assignments... for example, if the lecturer asks to make thumbnails or development, so we will do a little bit of development... so before the class, we will prepare the development that we've done... so during class, show it to the lecturer and get approval to proceed... "
(Respondent ID: 12)

3.3.4 Inter-relations between the learning conceptions, preference for instruction and learning approaches of design students (RQ 2)

The inter-relations between the three variables are examined using the Spearman's correlational analysis. Results of this analysis provide evidence that the *surface-reproducing learning conception* is related to participants' preference of instruction that focusses on the transmission of information, $r(190)=.72$, $p<0.01$ and the *surface learning approach*, $r(186)=.32$, $p<0.01$, as hypothesized in Section 3.

This analysis also shows that the *deep-transforming learning conception* is related to the *deep learning approach*, $r(187)=.36$, $p<0.01$, as hypothesized in Section 3. However, it does not show the hypothesized relation between the *deep-transforming learning conception* and preference for instruction that supports the development of personal understanding. Conversely, no significant correlations can be found between the *surface-reproducing learning conception* and *deep learning approach*, and between the *deep-transforming learning conception* to the *surface learning approach*. This strongly supports the notion that the *surface-reproducing learning conception* is exclusively related to the *surface learning approach,* while the *deep-transforming learning conception* is exclusively related to the *deep learning approach* (see Table 3.1).

Interesting to note is that the learning approach scales are positively correlated to one another. A positive correlation was found between the *deep learning approach* to the *strategic learning approach*, $r(186)=.40$, $p<0.001$. Additionally, a positive correlation was found between the *surface learning approach* and the *strategic learning approach*, $r(190)=.29$, $p<0.001$. A positive correlation was also found between the *deep learning approach* to the *surface learning approach*, $r(184)=.38$, $p<0.001$. The strategic learning approach is not significantly correlated to any of the learning conception scales. However, the strategic learning approach is positively correlated to preference for instruction that supports the development of personal understanding. This means that preference for the strategic learning approach is not related to students' internal mental disposition, unlike the deep and surface learning approaches.

Table 3.1 Correlations between learning approaches, learning conceptions and preference for instruction from ASSIST

	1	2	3	4	5	6
Learning approach						
1. Deep	-					
2. Strategic	.40***	-				
3. Surface	.35***	.29***	-			
Learning conception						
4. Surface-reproducing	.09	.04	.32**	-		
5. Deep-transforming	.36**	.07	.03	-.10	-	
Preference for instruction						
6. Transmitting information	.11	.02	.36**	.72**	-.09	-
7. Supporting understanding	.26**	.20**	.14	.05	.14	.08

**Correlation is significant at p< 0.01.

***Correlation is significant at p< 0.001.

These results also indicate that combinatory preferences of learning approaches are possible within participants, which provide good insights for interpreting mind-sets in design learning. For example, it can now be noted that two external responses are observable within the participants. Firstly, these participants strategically manage their time and study activities to either relate ideas, seek meaning and use evidence (deep learning approach), or to engage in unrelated memorising activities (surface learning approach). Secondly, and more importantly, the stronger inclination toward either the deep or surface learning approach within these participants are the relevant factors toward interpreting the different mind-sets in design learning.

Similar relationships between the three learning approaches can be observed within the semi-structured interviews. Participants 4, 5, 6 and 12 related highest frequencies of instances where they engaged in both deep and surface learning activities. Participants 1 and 3 related highest frequencies of instances where they engaged in both deep and strategic learning activities. Participants 2, 7, 8, 9, 10 and 11 related highest frequencies of instances where they engaged in both surface and strategic learning activities (see Appendix H). To illustrate how combinations of learning approaches can come to occur within participants, an example of extracts of the interview transcripts from one participant is presented as follows. Participant 5 related 57 instances that were related to the deep learning approach, 6 instances related to the strategic learning approach and 16 instances related to the surface learning approach (see Appendix H). During the interview, Participant 5 conveyed an instance of the deep learning approach where she displayed the tendency to relate ideas (see Quotation 16). She also indicated an instance where she displayed the tendency to organise her studying. This is related to the strategic learning approach (see Quotation 17). Participant 5 also conveyed the tendency to memorise, which is an instance of the surface learning approach (see Quotation 18).

Quotation 16
" What I think is important, I [will] take down what he [the design teacher] says, what he writes and also what he says, that I think is important. Sometimes he asks, what do you want to observe...? What do you want to design...? I will jot down what he asks or the things that he reminds us. After that I will look back and then relate it with my project, asking [back] the same questions to myself." ***(Respondent ID: 5)***

Quotation 17
" If I have the time, I will revise the lecture again. During the lecture, I will jot down everything that I think is important. Then, when I need to revise [for exams] again, I will go through my notes again." ***(Respondent ID: 5)***

Quotation 18
" I start to memorise the lecture because there is no time for me to understand it. For me to understand the lecture, is very time consuming. Then if last minute, I will need to memorise." ***(Respondent ID: 5)***

The extracts from Participant 5 clearly illustrate how the three learning approaches can occur within one design student. However, these inter-relations seem to entangle with one another, and the question arises as to whether significant differences in terms of learning approaches can be described. Thus, an exploratory comparison of the frequencies in terms of percentages was carried out to delineate any possible patterns from the frequencies of instances related to the three learning approaches.

Respondents were first grouped as belonging into high deep learning approach cluster or high surface learning approach cluster, depending on their more frequent indication of instances related to the deep or surface learning approach. When participants indicated high instances on both deep and surface learning approaches, they will be clustered either into the high deep or high surface learning approach cluster, depending on the higher amount of frequencies they indicated. For example, Participant 6 was clustered into the high surface learning approach cluster as she indicated 15 instances coded as the surface learning approach, and 13 instances coded as the deep learning approach (see detail of frequencies in Appendix H). Next, the percentage of instances related to each learning approach of both clusters are calculated for between clusters and within each cluster (see columns 1 to 4 in Table 3.2). The percentages of differences between the clusters are also calculated (see Column 6 in Table 3.2).

Table 3.2 Percentages of occurrences for the learning approach pattern codes between participants clustered as higher deep and higher surface clusters. (D): Deep learning approach, (SF): Surface learning approach, (ST): Strategic learning approach. Values in the "Between clusters" columns indicate the percentage of differences BETWEEN the high deep and high surface clusters. Values in the "Within cluster" columns indicate the percentage of differences within the high deep cluster OR within the high surface cluster.

Learning approach	High deep cluster Participants: *1, 3, 4, 5, 12*		High surface cluster Participants: *2, 6, 7, 8, 9, 10, 11*	High deep cluster Participants: *1, 3, 4, 5, 12*	High surface cluster Participants: *2, 6, 7, 8, 9, 10, 11*	
	Percentage of instances where learning approach were mentioned				Percentage of differences	
	Comparison between clusters (1)	Within cluster (2)	Comparison between clusters (3)	Within cluster (4)	Comparison between clusters (5)	Within cluster (6)
(D)	76%	54%	24%	17%	52%	37%
(ST)	34%	20%	66%	38%	32%	18%
(SF)	36%	26%	64%	45%	28%	19%

76% instances related to the deep learning approach are mentioned by participants in the high deep cluster, when compared to the high surface cluster. Participants in the high surface cluster only mentioned 24% instances related to the deep learning approach. A difference of 52% can be observed between these two clusters. This reveals that participants in the high deep cluster, mentioned approximately 3.2 times the amount of instances related to the deep learning approach compared to participants in the high surface cluster. In contrast, participants in the high surface cluster mentioned 64% instances related to the surface learning approach, while participants in the high deep cluster mentioned 36% instances related to the surface learning approach. A difference of 28% can be observed between these two clusters. This shows that participants in the high surface cluster mention approximately 1.8 times or almost double the amount of instances, related to the surface learning approach, compared to participants in the high deep cluster.

Participants in the high surface cluster also mentioned 66% instances related to the strategic learning approach, while participants in the high deep cluster mentioned 34% instances related to the strategic learning approach. A difference of 32% can be observed between these two clusters. This reveals that participants in the high surface cluster mention approximately 1.9 times or almost double the amount of instances, related to the strategic learning approach, compared to participants in the high deep cluster.

Within the high deep cluster, participants mentioned 54% instances related to the deep learning approach, 20% instances related to the strategic learning approach and 26% instances related to the surface learning approach. In comparison, participants within the high surface cluster mentioned 17% instances related to the deep learning approach, 38% instances related to the strategic learning approach and 45% instances related to the surface learning approach. This means that approximately half of the instances that the participants indicated regarding the learning approaches are related to their cluster style; deep learning approach to high deep cluster and surface learning approach to the high surface cluster. This provides useful indicators for the more distinctive adoption of deep and surface learning approaches by the participants. Additionally, in relation to the strategic learning approach, the percentage of instances indicated by participants in the high surface cluster is slightly higher, compared to that indicated by participants in the high deep cluster. Within the high surface cluster, the participants also mentioned almost double the amount of instances related to the strategic learning approach, compared to participants within the high deep cluster. This suggests that the participants in the high surface cluster are more acquainted with the strategic learning approach, compared to participants in the high deep cluster.

Following up on the quotations of Participant 5 as previously presented in this section, the deep learning approach that she mentioned, revealed another critical aspect of design learning: the design teacher. In Quotation 16, the design teacher is highly involved in enabling Participant 5 to start reflecting and relating ideas within her design project. This phenomena was also observed within the quantitative data. The deep learning approach was found to correlate to participants' preference for instruction that supports the development of personal understanding. Additionally, the surface learning approach was found to correlate to participants' preference for instruction that focusses on transmitting information (see Table 3.1). The qualitative data resonates with these quantitative findings (see Table 3.3).

Table 3.3 Summary of interrelations between participants' preference for instruction and learning approaches across all 12 respondents. PFI: U refers to preference for instruction and teachers that emphasize support understanding. PFI: I relates to preference for instruction and teachers that focus on transmitting information.

Cluster	Based on frequencies of occurrences	
	Total PFI:I	**Total PFI: U**
High deep cluster Participants: 1, 3, 4, 5, 12	18	22
High surface cluster Participants: 2, 6, 7, 8, 9, 10, 11	47	23

Participants in the high deep and high surface clusters were compared in terms of their PFI:I and PFI:U. Participants in the high deep cluster, that mentioned more instances related to the deep learning approach, indicated 22 instances related to PFI:U and 18 instances related to PFI:I in total. Additionally, participants in the high surface cluster, that mentioned more instances related to the surface learning approach, indicated 47 instances related to PFI:I and 23 instances related to PFI:U in total. This means that they clearly mention more instances related to PFI:I. As a matter of fact, they mentioned approximately double the amount of instances related to PFI:I, compared to PFI:U. These last numbers provide supporting evidence, to the quantitative data, of the interaction between the type of learning approach and type of instructions that participants would indicate to prefer.

3.3.5 Distinguishing mind-sets in design learning (RQ 2)

In order to distinguish mind-sets in design learning, the relation between the internal aspect of mind-sets (learning conception) and the external aspect of mind-sets (the type of instruction and learning approach that students would prefer) are tested. Participants in the high and low 'deep-transforming learning conceptions' (DTLC) were compared using the Independent T-test. Participants belonging to the high-deep learning conception (high DTLC) cluster (M=4.57, SD=0.29) indicated their responses as above the median-value of all participants, on the deep learning conception scale. In contrast, participants indicating their responses below the median-value were grouped as belonging into the low-deep learning conception (low DTLC) cluster (M=3.52, SD=0.61)(see Section 3.2.2). The two clusters consist of 93 and 97 participants respectively. This test reveals that participants can be differentiated in terms of their low and high deep-transforming learning conceptions.

Although no differences in terms of the surface-reproduction learning conception, preference for instruction that focusses on transmitting information and surface learning approach can be observed between these two cluster of participants, participants differed on, their preference for instruction that supports the development of personal understanding and deep learning approaches (see Table 3.4).

Participants in the high DTLC cluster (*M*=4.57, *SD*=0.29) indicated significantly higher learning conceptions related to deep-transforming compared to participants in the low DTLC cluster (*M*=3.52, *SD*=0.61); *t*(188)=-15.28, *p*=0.000. A large effect size of Cohen's *d*=2.20 indicates a large difference between the two groups with regard to their DTLC (see Table 3.4). Participants in the high DTLC cluster (*M*=4.02, *SD*=0.74) indicated higher preference for instruction that supports the development of their personal development (PFI:U) compared to the low DTLC cluster (*M*=3.72, *SD*=0.76); *t*(184.77)=-2.77, *p*=0.006. Participants in the high DTLC cluster (*M*=4.05, *SD*=0.43) also indicated higher preference for the deep learning approach compared to the low DTLC cluster (*M*=3.75, *SD*=0.49); *t*(185)=-4.49, *p*=0.000.

Table 3.4 T-test between high and low DTLC clusters

	Cluster 1: Low DTLC ***N=93*** ***(Mean, SD)***	**Cluster 2: High DTLC** ***N=97*** ***(Mean, SD)***	**Effect size, Cohen's *d***
Learning Conception			
Surface-Reproducing	3,77 (0,70)	3,95 (0,65)	0.27
Deep-transforming**	3,52 (0,61)	4,57 (0,29)	2.20
Preference for instruction			
Transmitting information	3,61 (0,82)	3,55 (0,93)	0.07
Supporting understanding*	3,72 (0,76)	4,02 (0,74)	0.40
Learning approach			
Deep **	3,75 (0,49)	4,05 (0,43)	0.65
Strategic	3,30 (0,74)	3,25 (0,82)	0.06
Surface	3,26 (0,61)	3,24 (0,70)	0.03

* T-test on average scores over two clusters was significant at p<0.05.

** T-test on average scores over two clusters was significant at p<0.001.

Within the qualitative data, two pattern codes that were generated, reveal distinct differences between the 12 participants who were interviewed. These pattern codes are related to the deep and surface learning approaches. The pattern code related to the deep learning approach is referred to as *faces challenges*. The pattern code related to the surface learning approach is referred to as *takes convenient measures* (see Table 3.5). The pattern code "*faces challenges*" is related to rising up to challenges that participants encounter in design learning, and it is regarded as characteristic of the deep learning approach (see Quotation 11 and Quotation 12Quotation 12). The pattern code "*takes convenient measures*" is related to participants' tendencies to engage in actions that would compromise deeper levels of processing in order to decrease their work load (see Quotation 13). This pattern code is regarded as characteristic of the surface learning approach.

Table 3.5 Frequencies of occurrences for the two pattern codes across all 12 respondents.

Pattern code: Learning Approach	Respondent No												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
Deep: Faces challenges	4	0	4	0	6	0	0	0	0	0	0	0	**14**
Surface: Takes convenient measures	0	11	0	6	0	9	1	2	1	3	2	2	**37**

Across the 12 participants, three of the participants (Participants 1, 3 and 5) that had conveyed instances where they rose up to challenges, had not indicated any instances where they would take actions to decrease their workload and compromise deeper levels of thinking (related to the pattern code: *takes convenient measures*. In contrast the remaining nine respondents that had indicated instances where they took actions that would decrease their workload and compromise deeper levels of thinking, these respondents did not indicate any instances related to *facing challenges.* This suggests that these two pattern codes uniquely characterises the deep and surface learning approaches. A network display was generated to map out and visualize the exclusive characteristic of the two pattern codes: its interactions between the learning approach and preference for instruction pattern codes; and its influence on the development of new pattern codes to describe the design learning mind-sets (Miles et al., 1994) (see Figure 3.1). The network display is divided into four parts. The exclusive pattern codes are situated within the second part of the network display.

Interactions between the learning approaches are situated within the first part of the network display. From the interview transcriptions, participants related instances where their deep learning approaches related to their surface and strategic learning approaches. In instances where their deep learning approach related to their surface learning approach, participants conveyed that they related ideas, used evidence, sought for meaning and took an interest in ideas, in conjunction to using limited evidence and executing unperceptive actions. This means that although they engaged in deep learning approaches, their actions were done in a limited and routine manner. However, in instances when their deep learning approach related to their strategic learning approach, participants engaged in deep learning activities in conjunction to monitoring their own effectiveness, organising their study activities and time; and

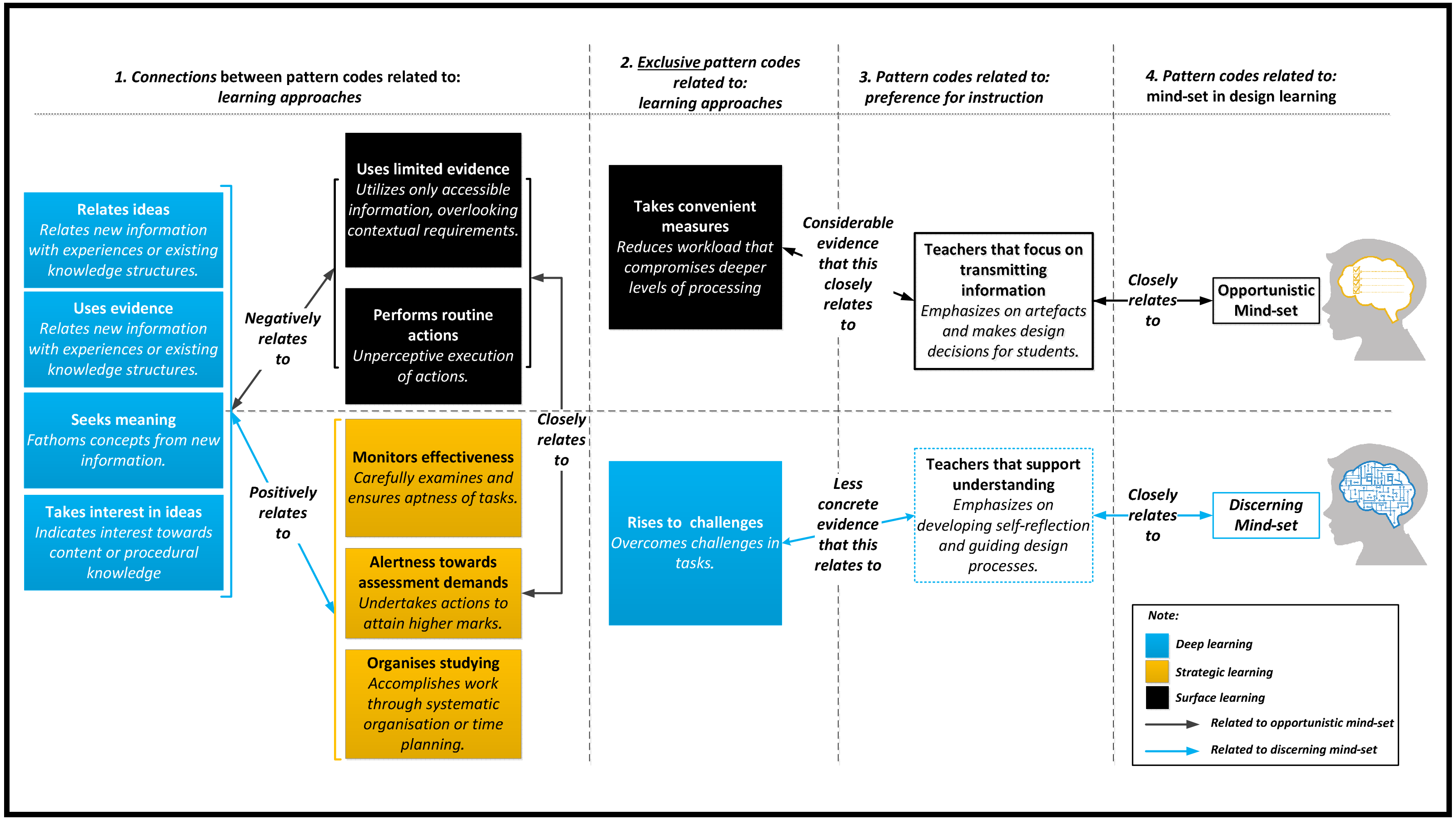

Figure 3.1 Pattern codes: Inter-relations between participants' learning approaches, preference for instruction and mind-sets in learning design

being alert toward assessment demands. This means that when they engaged in deep learning approaches, they would also monitor and organise their studying. This was done either through systematic management of their time or organisation of their study activities.

The third part of the network display contains two pattern codes related to participants' preference for instruction: (1) teachers that focus on transmitting information and (2) teachers that support understanding. The tendency to *take convenient measures* is found to closely relate to preference for *teachers that transmit information.* This can be observed from the following instance, where the participant discloses her tendency to seek out lecturers who will provide design decisions so that she does not have to make the decision by herself (see Quotation 18 and Quotation 19). When participants expressed instances where they rose up to challenges, they also expressed preference for teachers that focussed on guiding and developing self-reflection. Thus the inclination to *face challenges* as conveyed by participants are found to closely relate to their preference for *teachers that support understanding* (see Quotation 12).

Quotation 19
I have been in [ambiguous] situations... I will go and ask other lecturers... I will go and ask Lecturer 1... or go and ask other lecturers... because sometimes, some lecturers do not tell us... they won't tell us directly... so in that case, I will go and ask other lecturers [lecturers that will provide direct answers] ***(Respondent ID: 6)***

The interactions observed between pattern codes on the first three parts of the network display triggered the development of two new pattern codes to describe mind-sets in design learning. These two new pattern codes are situated within the fourth part of the network display, and referred to as the *opportunistic mind-set* and the *discerning mind-set*. The *opportunistic mind-set* pattern code emerged from (1) the counter-active interaction between deep and surface learning approaches; (2) the pattern code *takes convenient measures*; and (3) the association to the pattern code *teachers that focus on transmitting information*. The discerning mind-set pattern code emerged from (1) the positive interactions between strategic and deep learning approaches; (2) the pattern code *faces challenges*; and (3) the association to the pattern code *teachers that support understanding*.

3.3.6 The discerning and opportunistic mind-sets

The *discerning mind-set* is uniquely characterised by tendencies to discern ambiguity and raise up to the challenges they encounter. Participants inclining toward this mind-set disclosed through the semi-structured interviews that they tried to deeply engage with design problems that they encountered. They indicated instances where they sought to seek meaning between concepts, relate ideas and information, and use corroborative evidence to support the development of their design ideas and/or decisions. Additionally, participants indicated higher preference for teachers that supported the development of their personal understanding. This is associated to preferring teachers that focus on developing their self-reflection and guiding their design processes.

The *opportunistic mind-set* is uniquely characterised by participants' inclination to take convenient measures. Participants inclining toward this mind-set disclosed through the semi-structured interviews that they did not delve as deeply into design tasks that they were engaged in. They related instances where they contrived convenient strategies that are easily accessible to them, and avoided undesirable or difficult situations. This includes engaging in design tasks at a surface level and making superficial connections with non-corroborative evidence. Additionally, these participants indicated preference for teachers that focussed on transmitting information. This is associated to depending on teachers to make design decisions and focus on producing tangible artefacts that are required.

3.3.7 Cross-validating the mind-set categories in design learning

The associations that emerged from the qualitative data are used to validate the quantitative findings of the ASSIST questionnaire and summarized in Table 3.6 to corroborate the two proposed mind-sets. Quantitative and qualitative findings related to learning approach, preference for instruction and learning conceptions are illustrated in columns 1 to 9. From the quantitative data, participants were clustered according to their deep-transforming learning conceptions (DTLC). Participants in the high DTLC cluster (see column 8) represent the discerning mind-set category, while the low DTLC cluster represents the opportunistic mind-set category. From the qualitative data, five out of 12 of the participants for the semi-structured interviews (Participants 1, 3, 4, 5, and 12) represent the *discerning mind-set* group. Additionally, the seven remaining participants (Participants 2,6,7,8,9,10 and 11) represent the *opportunistic mind-set* group.

The *discerning mind-set* can thus be characterised by high preferences toward the: (1) deep transforming learning conception (see Column 8); (2) deep learning approach (see Columns 1 and 2); and (3) instruction and teachers that support understanding (see column 1 for correlations, Columns 5 for T-test, and Column 6 for qualitative evidence). Additionally, the *discerning mind-set* is uniquely characterised by inclination to rise up to challenges (see Column 4). In contrast, the *opportunistic mind-set* is characterised by low preference toward these same three variables. Qualitative evidence indicating that *opportunistic mind-sets* incline toward teachers that transmit information can also be found (see Column 6). Additionally, indirect

Table 3.6 Triangulation of quantitative and qualitative data that support the existence of the discerning and opportunistic mind-sets.

Design learning mind-sets	Learning Approach				Preference for instruction		Learning Conception	
		Qualitative data						
	Quantitative data	Categories	Respondent (s)	Distinguishing feature	Quantitative data	Qualitative data	Qualitative data	Quantitative data
	1	2	3	4	5	6	7	8
Discerning	**T-test:: Higher deep learning approach **Deep LA is correlated to: 1. PFI: (U) 2. LC: Deep-transforming	Deep	1,3,4,5,12,	Rises up to challenges	*T-test: Higher preference for instruction that supports understanding	More evidence for: Teachers that support understanding	n/a	** T-test: : High Deep-transforming
Opportunistic	**T-test:: Lower deep learning approach **Surface LA is correlated to: 1. PFI: (I) 2. LC: n/a	Surface	2,6,7,8,9, 10,11,	Takes convenient measures	* T-test: : Lower preference for instruction that that supports understanding	More evidence for: Teachers that transmit information	n/a	** T-test: : Low deep-transforming

**Correlation is significant at p< 0.01.

***Correlation is significant at p< 0.001.

* T-test on average scores over two clusters was significant at p<0.05.

** T-test on average scores over two clusters was significant at p<0.001.

evidence for the opportunistic mind-set to prefer the surface learning approach and instruction that focusses on transmission of information can be observed (see Column 1). Additionally, the *opportunistic mind-set* is uniquely characterised by tendencies to take convenient measures.

3.4 Discussion and Conclusion

The nature of mind-sets in design learning can be described by the learning conception, learning approach and instruction that a design learner prefers to incline toward. Participants that indicated higher preference for the *deep learning approach* had also indicated higher preference for instruction that supports understanding. Therefore, although the *deep-transforming learning conception* is not directly correlated to the hypothesized preference for instruction (see Table 3.1), it is significantly correlated to the *deep learning approach*, which in turn, is significantly correlated to preference for instruction that supports understanding. This strongly implies that participants' conception of learning can influence the learning approach that they would prefer to adopt in learning. When they hold a *surface-reproducing learning conception* of learning, they would be more likely to prefer the *surface learning approach*. When they hold a *deep-transforming learning conception* of learning, they would be more likely to prefer the *deep learning approach*.

These results also provide evidence that the learning approaches that participants prefer to adopt are related to the type of instruction that they prefer to receive. When participants indicated higher preference for adoption of the *surface learning approach*, they also indicated higher preference for instruction that focusses on transmitting information. On the other hand, when participants indicated higher preference for the *deep* and *strategic learning approaches*, they indicated higher preference for instruction that supports understanding (see Section 3.3.4).

The *discerning learning mind-set* associates more strongly to the preference of teachers or instruction that support understanding, the conception of learning as related to the development of personal understanding, and the deep learning approach. The *opportunistic learning mind-set* category associates more strongly with preference for instruction or teachers that focusses on the transmission of information, the conception of learning as a means of reproducing knowledge, and the surface learning approach. The strategic learning approach which is relates to the strategic management and organisation of time and studying, varies from low to high levels of the strategic learning approach between the two mind-sets.

The notion of *discerning* and *opportunistic* mind-set in design learning have been shown to closely associate to the learning conception that a learner holds, the learning approach that a learner would prefer to adopt and the type of instruction that they would prefer to receive or engage in. The *discerning mind-set* associates learning for understanding and personal development. This in turn, relates to the types of instruction that they would prefer to engage with, and the distinct approaches that they would prefer to adopt in learning (Entwistle & Ramsden, 2015). Students that incline toward the *discerning mind-set* prefer to receive instruction that supports understanding and engage in deep and strategic-monitoring learning approaches. This means that students in the *discerning mind-set* cluster prefer to seek meaning and relate ideas when presented with information. They would also be motivated to do well in their studies and incline toward systematic monitoring of content-related aspects of studying. Students inclining toward the *discerning mind-set* have also been found to develop design ideas or making decisions based on corroborative evidence (see Section 3.3.5).

The inclination to take mental shortcuts in preference to thinking things through causes fallacies in thinking (Corno & Anderman, 2016). The effects of these fallacies can be observed within students that gravitate toward the *opportunistic mind-set*. These students associate learning to the reproduction of information. Consequently, students that incline toward this mind-set prefer to receive instruction that focusses on the transmission of information, and engage in surface learning approaches, and minimal strategic learning approaches. This means that students in the opportunistic mind-set cluster incline toward memorising when presented with information. They also become bounded to a course syllabus and are prone to experiencing a lack of purpose throughout their education. Students inclining toward the opportunistic mind-set have also been found to take convenient measures and not delve deeply into the design tasks that they engage in (see Section 3.3.5). They indicated tendencies to contrive upon convenient strategies that are accessible, and would avert undesirable or difficult situations. This includes engaging in design tasks at a surface level and making superficial connections with non-corroborative evidence.

Consistent findings within the quantitative and qualitative data sets have been consolidated within this study. However, the validity of these proposed mind-sets must be assessed and further tested. The validity of the proposed mind-sets are externally validated and tested in the next two empirical studies presented in Chapters 4 and 5. The current findings provide a platform to enable a systematic investigation. Knowledge gained from this chapter raises interesting issues regarding the implications of the distinct mind-sets, which are yet to be investigated. For example, what other individual attributes or dispositions are related to the *discerning* and *opportunistic* mind-sets? In other words, what other aspects can be taken into consideration to better understand these mind-sets? Additionally, does the *discerning learning mind-set* necessarily enable students to achieve better performance in their learning? Furthermore, building on that assumption, does this also mean that the students that incline toward the *opportunistic learning mind-set* will attain poorer results in accomplishing a design task? Given these points, can the design learning experience be improved? These aspects are investigated to achieve a better understanding of the two design learning mind-sets. The characteristics of these design learning mind-sets are expected to be clarified through the rigorous experimental design that was set-up for the second empirical study. Findings are presented in the subsequent chapters of this thesis.

4

Differences between the discerning and opportunistic mind-sets

In the previous chapter, two mind-sets were proposed: the discerning and opportunistic mind-sets. These two mind-set clusters are however, still a tentative clustering of the way students feel, think and behave in learning that requires validation. Subsequently, key differences between the two mind-sets are investigated in this chapter, using a quasi-experimental study. In this chapter, results of this study are presented. Design students filled in a questionnaire and solved a design problem. Data collected relates to (1) students' individual dispositions that include their perceived self-efficacy, tolerance for ambiguity, view of their own intelligence and preferred learning approaches; (2) the prevalence of difficulties and types of questions students ask when solving a design problem; and (3) the quality of design solutions that the design students produce. This study reveals the differences between design students that incline toward the discerning and opportunistic mind-set, on these three variables. Next to this, an intervention to promote reflection is also introduced to test if better quality design solutions can be produced, depending on the mind-set that a student inclines toward. This intervention however, did not result in any significant differences. Results from this study provide further insight regarding the different design learning mind-set types and reveal persuasive evidence for the two design learning mind-sets proposed in Chapter 3.

4.1 Research aims, hypotheses and questions

The primary aim of this empirical study was to externally validate the individual differences between students that incline toward the discerning and opportunistic mind-sets, as proposed in the previous empirical study. These individual differences include four variables in the presage level of the 3P model, that are assumed to inherently exist within students (Biggs, 2012; Cruickshank, 1986; Huitt, 2003) (see also Figure 2.2 in Chapter 2). In view of the fact that design students have to deal with unstructured and open-ended problems in learning to design (Rittel & Webber, 1973; Buchanan, 1992; Coyne, 2005), four variables were selected. These variables are related to design students' perception of their self-efficacy, their tolerance for ambiguity, their view of own intelligence and their preferred learning approaches. These variables, are in turn, anticipated to influence the process and outcomes of a person's design process.

Self-efficacy pertains to a students' evaluation of his or her capability to accomplish a task successfully (Pintrich & de Groot, 1990). High self-efficacy has been found to result in higher achievement scores (Grant & Dweck, 2003; Miller et al., 1996; Pintrich & de Groot, 1990). However, an underestimation of performance has been shown to result in self-regulatory behaviour which improved students' performance (Christensen et al., 2002). Self-regulatory behaviour, requires conscious contemplation and controlled processing of learning activities (McLaughlin, 1990). Results from the previous study demonstrate that the discerning mind-set is closely associated to a deep learning approach, a conception that learning is related to the enhancement of personal understanding and individual development (see Table 3.7 in Chapter 3). The opportunistic mind-set, on the other hand, is associated to the surface learning approach and the tendency to contrive upon convenient strategies that become accessible (Hamat et al., 2015).

Building upon these notions, design students inclining toward a discerning mind-set are expected to associate themselves with lower levels of self-efficacy. This is because lower estimations of self-efficacy possibly occurs due to a more mindful or conscious act of gauging one's own performance. In addition, these students are expected to achieve higher levels of outcome achievements (Christensen et al., 2002). In contrast, design students that incline toward an opportunistic mind-set are expected to associate themselves with higher levels of self-efficacy due to a less mindful deliberation of their own performance. Consequently, these students will be more likely to perform less competently. As design students that incline toward the opportunistic mind-sets are expected to be associated to higher levels of self-efficacy, thus they are also expected to be associated to higher levels of tolerance for ambiguity (Endres et al., 2015). Therefore, it can be expected that students that incline toward the discerning mind-set will have lower tolerance for ambiguity.

Ambiguous situations are more likely to be perceived as a difficult situation, which is in inherent in design learning. Designing is inherently an ambiguous situation (Buchanan, 1992; Coyne, 2005). Individuals with low tolerance for ambiguity tend to avoid ambiguous situations i.e., difficult situations in design learning (Furnham & Ribchester, 1995). This fundamentally contradicts with the assumption that students inclining toward the opportunistic mind-set will have higher tolerance for ambiguity, as these students were found to avoid difficult situations in design learning (see Section 3.3.6). It is also possible that students inclining toward the opportunistic mind-set will incline toward a low tolerance for ambiguity. Students inclining toward the discerning mind-set showed that they would overcome challenges i.e., difficult situations in their learning tasks (Hamat et al., 2015). This indicates that they are more likely to have a higher tolerance for ambiguity. It is thus possible for varying levels of tolerance for ambiguity between the two mind-sets.

Design students inclining toward the discerning mind-set are also expected to hold an incremental view of their own knowledge. This is because they perceive learning as an enhancement of personal understanding and individual development (Hamat et al., 2015). This means that they would view their intelligence as developable through effort (Miller et al., 1996; Bråten & Olaussen, 1998; Ablard, 2002; Dupeyrat & Mariné, 2005). Design students inclining toward the opportunistic mind-set are expected to hold a contrary view of their own intelligence compared to design students that incline toward the discerning mind-set. They are expected to hold an entity view of their own intelligence. This pertains to students viewing their own intelligence as an in-built or natural ability (Dupeyrat & Mariné, 2005; Dweck, 2006, 2015). To test the hypothesized relationships between the variables discussed the first research questions is formulated as follows:

> *RQ 1. How do students' individual attributes that include their perception of self-efficacy, tolerance for ambiguity, view of own intelligence and preferred learning approaches relate to the discerning and opportunistic design learning mind-sets?*

Individual differences between the two mind-sets are, in turn, expected to influence the design process that students engage in. The type of questions students ask throughout the process of solving design problems are considered to be closely related to decisions that they subsequently make (Eris, 2003; Aurisicchio et al., 2007). The activity of question asking also forms an essential component that relates to deeper levels of processing, required in learning design (Graesser & Person, 1994). Throughout their design process, the question-asking tendencies of the discerning and opportunistic mind-sets are expected to differ. The types of questions that students ask throughout their design process can be categorised into a range of levels from low to high standing questions (Eris, 2003; Graesser & Person, 1994). Low level questions are related to clarifying missing or incomplete information in relation to the design context, while high level questions include (1) *deep reasoning questions* that seeks to find rational explanations by converging onto facts related to design context; and (2) *generative design questions* that diverge away from facts, to possibilities that can be generated (Eris, 2004). The proper ordering and incremental formulation of questions across these levels yield more reliable forms of knowledge (Dillon, 1984;

Eris, 2002). This means that when students attempt to, firstly, clarify the missing information that are relevant to their design projects, secondly, proceed to increase their understanding of the related design contexts through deeper inquiry, and finally, proceed to explore the various range of possibilities that are related to the design context, they will be able to generate more plausible knowledge that would enable the generation of better design solutions.

Based on these notions, it is more likely that the discerning mind-sets would engage in proper incremental question-asking formulations. Additionally, abrupt or expeditious question-asking formulations can be expected from the opportunistic mind-sets that incline toward making superficial connections with non-corroborative evidence (Hamat et al., 2015). Equally important is the level of difficulty of a problem perceived by participants, which can potentially influence their performance when solving design problems (Frenseh & Funke, 2014). It has been suggested that the average level of task difficulty as opposed to lower or higher levels of difficulty correlates highest with better performance (Frenseh & Funke, 2014). For these reasons, these two variables are examined to gain insight into students' problem solving process. These variables include, firstly, the type of questions that participants would ask related to the design task that they were given and, secondly, whether they faced any difficulties while working on the task. In practice, these aspects would similarly exist within a design project. By examining these aspects, better insights of their processes can be obtained.

The design outcomes that design students produce, are also expected to differ in terms of quality when they incline toward the discerning or opportunistic mind-sets. Good quality solutions are expected to have high *relevance* and *specificity* (Dean et al., 2006). *Relevance* encompasses the *applicability* and *effectiveness* of a solution. *Applicability* refers to "the degree to which the idea clearly applies to the stated problem". *Effectiveness* refers to "the degree to which the idea will solve the problem". Hence, students inclining toward a discerning mind-set are expected to produce solutions that applies to the problem and will solve the problem to a higher degree, compared to students that incline toward an opportunistic mind-set. *Specificity* encompasses the *completeness* and *implicational effectiveness* of a solution. *Completeness* refers to the breadth of coverage that the solution addresses. It encompasses the number of independent sub-components into which the solution can be decomposed into. *Implicational explicitness* refers to "the degree to which there is a clear relationship between the recommended action and the expected outcome". Thus, students inclining toward a discerning mind-set are expected to produce solutions that solves a wider range of related aspects to the problem. That is, to a higher degree compared to students that incline toward an opportunistic mind-set. To test the hypothesized relationships of the discerning and opportunistic mind-sets in terms of their design process and outputs, the second research question is formulated as below:

> *RQ 2. Does the design process that students engage in and the quality of design solutions they produce differ between students with a discerning and opportunistic mind-set?*

It has been suggested that skill and meta-skill can be induced through instruction to promote successful problem solving in academic settings (Mayer, 2001). In design learning, this refers to knowledge of design methods or theories (skill) and the knowledge of strategies to manage the design methods (meta-skill). The design process and, subsequently, design outcomes that a student produces are thus also expected to be positively affected by these forms of stimulations. It has been suggested that deeper modes of reflection manifest within a reader as he or she starts to deliberate and contextualise the content of a text (Hochman, 2016). Depending on the content of the text that a student reads, it is expected that skills and meta-skills related to designing can be stimulated. *Skill* refers to the ability to draw upon knowledge which is specific to the required domain of the task or problem at hand (Mayer, 2001; McCombs, 1988). For example in design learning, this relates to knowledge of design processes and design methods. *Meta-skill* relates to the know-how of "when to use and how to coordinate" the skills in designing (Mayer, 2001, p. 91). This similarly refers to the understanding of when and how to use design methods throughout the design process. Consequently, it is expected that when design students are introduced to texts that contain relevant information regarding design processes and methods, along with the "when and how's" of this knowledge domain, the quality of solutions that they produce will improve. In order to test this assumption, the third research question is formulated as follows:

> *RQ 3. Can the quality of students' design outputs be improved by introducing design theory-oriented stimuli?*

4.2 Conceptual framework

To answer the research questions posed in the previous section, the conceptual framework proposed in Chapter 2 is used (see Figure 4.1). The conceptual model consists of three levels. These levels include the presage, process and product levels.

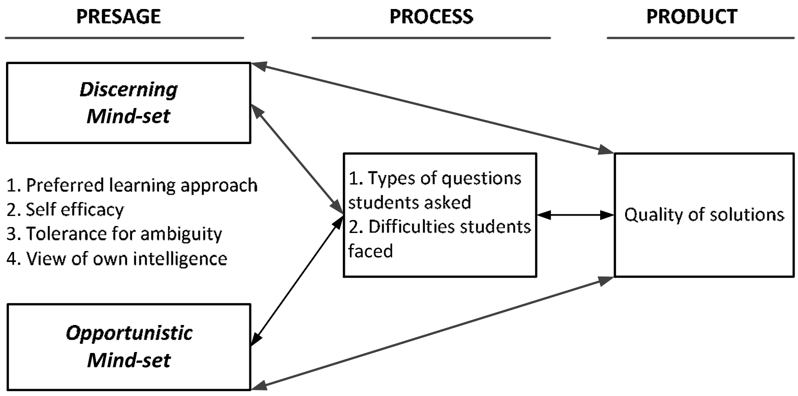

Figure 4.1 Theoretical model. This model shows the different variables on the Presage-Process-Product levels of the 3P model and the expected influences

On the presage level, four variables are assessed. This includes students' preferred learning approach, self-efficacy, tolerance for ambiguity and view of own intelligence. On the process level, two variables are examined. This includes the types of questions that students asked regarding the design task that they had to solve, and the occurrence of difficulties they faced throughout the task of designing. On the product level, the quality of solutions generated by students are examined.

4.3 Methods

A quasi-experimental study with control group design was used in this study (Kumar, 2011; Cohen et al., 2007). This experimental set-up is chosen as the control group design set-up allows to examine any prevalent effects of the planned intervention by comparing the *control* and *experimental group*. This research design is required to answer the third research question. Additionally, it allows to obtain data related to all three *presage, process* and *product* levels. This is essential for answering the first and second research questions.

4.3.1 Participants

91 design students from two universities in Malaysia were recruited for this study. The focus on Malaysian students allows to control for the cultural differences that were observed in the prior study (compare Hofstede, 2011; Hofstede & Jan, 2014).The participants were enrolled in their first or final year of the industrial, product or automotive design programmes. Out of all but one of the participants that reported their age and gender, 49 were male and 41 were female. Participants ranged between 20 to 27 years old.

4.3.2 Experimental procedure

The duration of the experiment ranged from one and a half to two hours. Slightly different procedures for the experimental and control group were used (see Figure 4.2). In both groups, participants were given a design brief related to transportation problems in the city of Kuala Lumpur, Malaysia (see Appendix K). This design problem was developed based on an example presented in a book entitled Design Methods (Jones, 1992). Further discussion on the choice of this design brief will be discussed later on in this section.

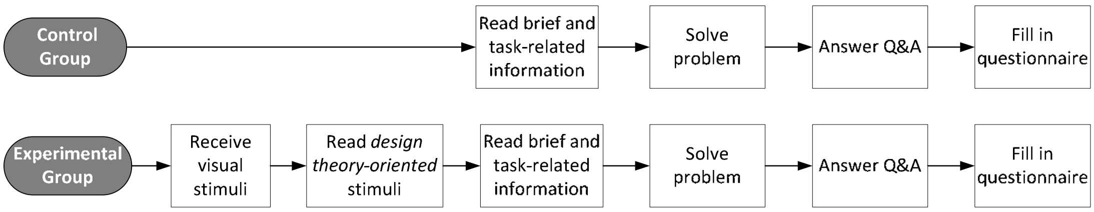

Figure 4.2 Overview of the procedure for the control and experimental groups

Prior to receiving the design brief and task-related information, participants in the experimental group were given a visual stimuli, followed by the design theory-oriented stimuli. The visual stimuli is meant to prevent participants from thinking of the subsequent design task, as they were reading the design theory-oriented stimuli. This visual stimuli was adopted based on suggestions by two research experts, with more than 30 years of experience in the field of research in psychology and design, and familiarity with experiment designs. They suggested this visual stimuli as an attempt to equalize the mental onset between control and experimental groups at the start of the design task. The visual stimuli contained the pictures of current electronic gadgets available in the market question. In addition, it contained the question "What should be developed next?". The design theory-oriented stimuli is a hand-out that participants had to read. It contains information on a design theory and a design method (see Appendix J). Similar to the design brief used for this study, the design theory-oriented stimulus was developed based on content from the book entitled Design Methods (Jones, 1992).

Except for the abovementioned stimuli, the remaining procedure for the experimental group was same to that of the control group. Participants were given a handout which contained information related to the design problem, such as issues related to public, private and non-motorised forms of transportation (see Appendix K), along with the design brief. Participants were then asked to produce conceptual solutions to the given design problem. A template was provided for participants to work out their solutions (see Appendix L).

The template was developed based on an existing template that was used within a Massive Open Online Course (MOOC) called "Product Design: The Delft Design Approach" (Daalhuizen & Schoormans, n.d.). This MOOC was developed in the Industrial Design Engineering Faculty of TU Delft University, the Netherlands. This template was used as suggested by the two previously mentioned research experts. The use of the template was meant as a measure to control for the possible immense disparities within the solutions that participants would provide. Participants were required to develop around five solutions to completely solve the transportation problem. They were next asked to pick their best solution and suggest concrete ways for its realisation and implementation. This procedure worked well within the MOOC, and was adopted for this study.

After solving the design problem, participants were subjected to a Q&A session. Questions were asked by trained interviewers and responses given by the participants were noted down on a prepared template (see Appendix L). This was done with participants in one university, while participants from the second university were asked to read through the questions individually and note down their responses on the prepared templates themselves, due to unavoidable logistical constraints. Questions in the Q&A session were formulated to elicit students' evaluation of the task. For example, students were asked about how they felt about the task, whether the task was difficult, and whether they learned anything new. Finally, participants were asked to fill in a 40-item questionnaire. Entwistle et al.'s (1997) ASSIST questionnaire was adopted to measure students' preferred learning approaches (15-items) and perceived self-efficacy (1-item). Norton's (1975) MAT-50 was adopted to assess students' tolerance for ambiguity (18-items). And finally, questions inquiring about students' view of their own intelligence were adopted from Dweck (2006) (6-items). Items were mainly used in their original form. Apart from 1-item that assesses the self-efficacy of students on a scale of 1 to 9, all other items were measured using a Likert-scale of 1 to 5.

4.3.3 Questionnaire scales and items

Entwistle et al's (1997) ASSIST questionnaire was adopted to measure the learning approaches that students preferred along with their perceived self-efficacy. This questionnaire originally consists of 52-items. Items related to the learning approaches that participants prefer are assessed on three scales. These scales include the deep, surface and strategic learning approaches. These scales have prevailed in several other studies that yielded appropriate validity levels (Duff, 1997; Speth et al., 2007; Reid et al., 2012; Brown et al., 2015). However, based on the previous study that used all 52-

items originally in the ASSIST questionnaire, the factor analysis reveals that 15-items with high factor loadings were sufficient to measure learning approaches on the three scales (see Section 3.3.1 in Chapter 3) (see also Hamat et al., 2015). Thus, these 15-items were used (see Table 4.1). All of these items were used in its original form and kept unchanged.

Table 4.1 Scales and items to assess students' preferred learning approaches and self-efficacy

Learning Approaches (Scale 1: Strongly Disagree to 5: Strongly Agree)		
Deep LA	**Surface LA**	**Strategic LA**
1. When I read, I examine the details carefully to see how they fit in with what's being said.	6. I concentrate on learning just those bits of information I have to know to pass.	11. I don't find it at all difficult to motivate myself.
2. When I am reading, I stop from time to time to reflect on what I am trying to learn from it.	7. I gear my studying closely to just what seems to be required for assignments and exams.	12. I usually plan out my week's work in advance, either on paper or in my head.
3. Often I find myself questioning things I hear in lectures or read in books.	8. Much of what I'm studying makes little sense: it's like unrelated bits and pieces.	13. I generally make good use of my time during the day.
4. Regularly I find myself thinking about ideas from lectures when I'm doing other things.	9. There's not much of the work here that I find interesting or relevant.	14. I'm pretty good at getting down to work whenever I need to.
5. Before tackling a problem or assignment, I first try to work out what lies behind it.	10. I find I have to concentrate on just memorizing a good deal of what I have to learn.	15. I organize my study time carefully to make the best use of it.
Self-efficacy (Scale 1: Rather badly to 9: Very Well)		
Finally, can you please indicate how you scored on your design work, so far?		

Items used to assess the level of tolerance for ambiguity within participants were adopted from Norton's (1975) Measure of Ambiguity Tolerance (MAT-50). This instrument yielded high correlations of r>0.80 in terms of internal reliability and test-retest reliability (Norton, 1975). This instrument originally assesses tolerance for ambiguity on eight different scales. Three scales that are assumed to be closely related to the context and situations related to learning in design was selected after discussions with the two previously mentioned research experts in questionnaire (see Table 4.2).

The three scales used in this study include the *Interpersonal communication, Problem-solving* and *Job-related* scales. The three scales consist of 18-items out of the original 61-items of the MAT- 50.

Table 4.2 Scales and items to assess students' tolerance for ambiguity

Tolerance for ambiguity (Scale 1: Strongly Disagree to 5: Strongly Agree)		
Interpersonal Communication	**Problem Solving**	**Initially: Job-related**
1. I prefer telling people what I think of them even if it hurts them, rather than keeping it to myself.	6. I do not like to get started in group projects unless I feel assured that the project will be successful.	15. I function very poorly whenever there is a serious lack of communication in critique sessions.
2. It irritates me to have people avoid the answer to my question by asking another question.	7. Complex problems appeal to me only if I have a clear idea of the total scope of the problem.	16. When I'm being evaluated in assessments, I feel a great need for clear and explicit evaluations.
3. I really dislike it when a person does not give straight answers about himself.	8. In a problem-solving group it is always best to systematically handle the problem.	17. If I am uncertain about my responsibilities in a design team, I get very anxious.
4. It really disturbs me when I am unable to follow another person's flow of thought.	9. In a decision-making situation in which there is not enough information to process the problem, I feel very uncomfortable.	18. At the end of the semester, I might become frustrated because my design would never be completed (design will never be perfect)
5. I tend to be very frank with people.	10. Once I start a task, I don't like to start another task until I finish the first one.	
	11. Before any important job, I must know how long it will take.	
	12. I don't like to work on a problem unless there is a possibility of coming out with a clear-cut and unambiguous answer.	
	13. A problem has little attraction for me if I don't think it has a solution.	
	14. A group meeting functions best with a definite agenda.	

Slight modifications were made to the items in order to make explicit reference to specific design learning activities. Modifications of the items were discussed together with the two previously mentioned research experts. Items were re-worded to convey a design-related context. For instance, an item originally structured as *"If I am uncertain about the responsibilities of a job, I get very anxious"* was modified into *"If I am uncertain about my responsibilities in a design team, I get very anxious".* In this case, the job-related item was modified to fit the context of a design team.

Six items were adapted from Dweck (2006) to assess participants' view of their own intelligence. These items have been tried and tested yielding high internal reliability values (Dweck et al., 1995). These items are assessed on two scales, which are the growth and fixed scales (see Section 2.3.1.4). Three items are assessed in each of these scales, on a 5-point Likert-scale. High agreement to the growth scale is related to an individual perceiving his/her intelligence and design capability as developable through effort. High agreement to fixed scale is related to an individual perceiving their intelligence and design capability as an in-built or natural ability. Disagreement on either the growth or fixed scale, reflects an affinity for the opposite scale. This means that when an individual scores themselves low on the growth scale, it also indicates a high score on the fixed scale. The opposite case stands for the fixed scale (see Table 4.3).

Table 4.3 Scales and items to assess students' view of their own intelligence

Mind-set (Scale 1: Strongly Disagree to 5: Strongly Agree)	
Growth	**Fixed**
1. You can always significantly change how intelligent you are.	4. Your intelligence is something very basic about you that you can't change very much.
2. No matter how much design capability you have, you can always change it quite a bit.	5. You can learn new things but you can't really change how your design capability is.
3. If you are given another opportunity, you would like to try a much more challenging task.	6. If you are given another opportunity, you would like to try to do the same task again.

4.3.4 Pre-analysis: Reliability of the scales

The reliability of the scales used in this study are analysed using Cronbach's alpha, α. Cronbach's alpha, along with the original and final numbers of items, are presented in the following Table (see Table 4.4). The scales originally comprised of 15 items for learning approaches, 18 items for tolerance for ambiguity and 6 items for view of own intelligence.

Table 4.4 Reliability of subscales

Scale	Cronbach's Alpha, α	Original number of items	Final number of items
Deep Learning Approach	0.62	5	2
Surface Learning Approach	0.70	5	3
Strategic Learning Approach	0.65	5	2
Tolerance for ambiguity	0.72	18	16
Fixed View of Own Intelligence	0.73	3	2
Growth View of Own Intelligence	0.39	3	2

High reliabilities of Cronbach's α=0.70, 0.72 and 0.73 can be calculated for scales of the surface learning approach, tolerance for ambiguity and fixed view of own intelligence subscales respectively. Relatively low reliability, Cronbach's α=0.62 and 0.65 is calculated for the deep and strategic learning approach scales correspondingly. Additionally, the growth view of own intelligence scale yielded an extremely low reliability of Cronbach's α=0.39. Spearman's correlational analysis reveals a small positive correlation between the two growth scale items, r (87)=.26, p=0.013. Spearman's correlational analysis for the fixed view of students' own intelligence scale yielded a moderately strong positive correlation, r (87)=.55, p=0.000.

4.3.5 Pre-analysis: Design process variables

Variables related to the design process of participants were assessed based on the responses that were recorded on a template during the Q&A session (see Appendix L). Responses were first deductively coded based on a "provisional start list of codes" (Miles et al., 1994, p. 81) for the types of questions that participants asked throughout their design process (see Appendix Q). This list consisted of low level and high level questions. High level questions encompass deep reasoning and generative design questions (Eris, 2002). According to Eris (2002), low level questions primarily relate to the clarification on missing or incomplete information. An example of a low level question is "What type of metal is this part made of?" On the other hand, deep reasoning questions are related to finding or judging causal explanations of a phenomenon. An example of a deep reasoning question would be "Why did this structure fail?" Finally, generative design questions leads to the reframing of contexts and concept generation. An example of a generative design question is "How about if we try it in that context?"

Low level, high level and generative design questions can be regarded as an incremental form of classification, where the questions are ordered from lower to higher levels. Proper ordering and incremental formulation of questions across the levels yield more reliable forms of knowledge (Dillon, 1984; Eris, 2002). Furthermore, when participants indicated facing a problem/problems during their engagement with the design task, these responses were also calculated. Some participants indicated facing one or more difficulties, while others did not indicate any difficulties at all.

4.3.6 Pre-analysis: Solution quality

The solutions that participants produced consisted of sketches and textual explanations. Some students sketched out and partially described their solutions with textual explanations while others fully described them in textual form (see Figure 4.3).

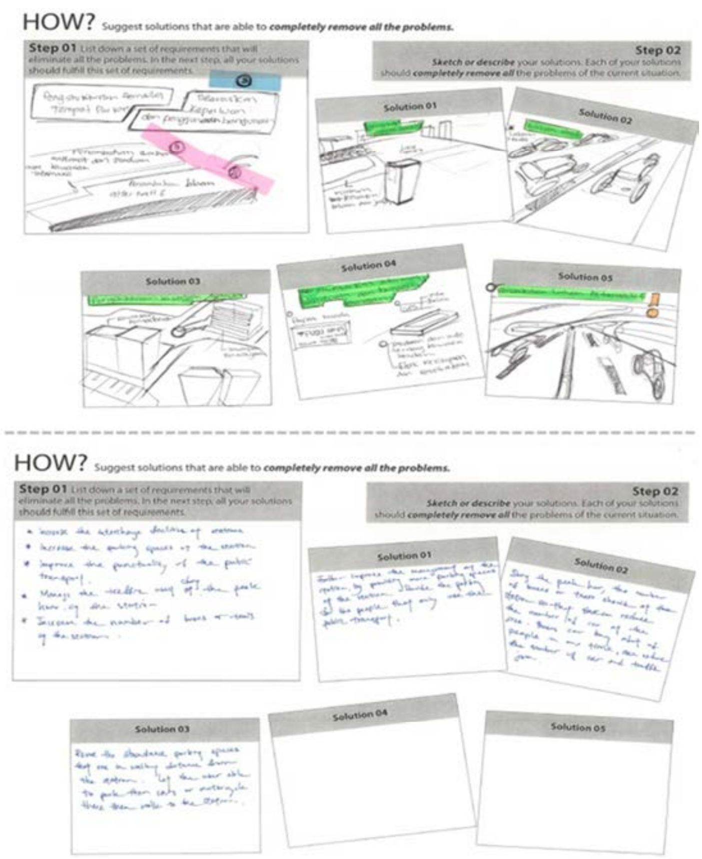

Figure 4.3 Examples of solutions provided by students. Top: Graphical and textual. Bottom: Textual only.

Each participant generated between one and five solutions for the design task, accumulating a total of 285 solutions. This number of solutions were obtained subsequent to the removal of repetitive ideas or statements. Additionally, when participants provided both general and detailed versions of an idea, only the detailed versions were taken into account (Bouchard and Hare, 1970 as cited in Dean et al., 2006; Connolly et al., 1993). These methods of streamlining the data are commonly used in the assessment of idea quantities (i.e. idea counting approaches), and are considered suitable for determining the overall number of solutions per participant for this study. Short textual descriptions of students' solutions were typed in identical formats for subsequent assessment of their quality (Gallupe et al., 1992; Garfield et al., 2001).

The 285 solutions that were generated by the participants were assessed on the four sub-scales. The *relevance* of a solution is measured on two sub-scales: *applicability* and *effectiveness.* The *specificity* of a solution is measured on two sub-scales: *completeness* and *implicational effectiveness*. All solutions were assessed by the author as a first rater, using a Likert-scale of 1 to 5 to assess each sub-scale (see for details of the scales). Subsequently, as a measure of reliability, 21% of the solutions were cross-checked by two independent coders, as second and third raters, using the same four sub-scales assessing quality. The scores on all four sub-scales of quality were next correlated using Spearman's correlation to assess the level of inter-rater reliability between the three raters. The two independent coders are both industrial design students with a BSc in Industrial Design who volunteered for the assessment. Prior to the actual evaluations, the two independent coders were given solution samples and trained on the procedure for scoring the solutions (Dean et al., 2006). This step was taken to ensure high inter-rater reliability between the raters. On the four scales of quality, moderate to high Spearman's correlations ranging from r=.55 to r=.90 are found between all three raters (see Table 4.5).

On the *completeness* scale, positive correlations could be found between raters 1 and 2; $r(60)$=.85, p<0.01, between raters 1 and 3; $r(60)$=.76, p<0.01, and between raters 2 and 3; $r(60)$=.90, p<0.01. On the *implicational explicitness* scale, positive correlations could also be found between raters 1 and 2; $r(60)$=.82, p<0.01, between raters 1 and 3; $r(60)$=.75, p<0.01, and between raters 2 and 3; $r(60)$=.81, p<0.01. On the *effectiveness* scale, positive correlations could be found between raters 1 and 2; $r(60)$=.73, p<0.01, between raters 1 and 3; $r(60)$=.69, p<0.01, and between raters 2 and 3; r (60)=.76, p<0.01. Finally on the *applicability* scale, positive correlations could be found between raters 1 and 2; $r(60)$=.55, p<0.01, between raters 1 and 3; $r(60)$=.62, p<0.01, and between raters 2 and 3; $r(60)$=.58, p<0.01. Although lower correlations could be observed for the *applicability* and *effectiveness scales* as opposed to the former two scales, these moderately high to high correlations still support the reliability of the ratings.

Table 4.5 Spearman's correlations between the three raters

Quality Sub-scale (Mean, SD)	Rater	Rater 1	Rater 2
Completeness	1	-	
(*M*=13.72, *SD*=2.80)	2	.85**	-
	3	.76**	.90**
Implicational explicitness	1	-	
(*M*=16.54, *SD*=5.20)	2	.82**	-
	3	.75**	.81**
Effectiveness	1	-	
(*M*=11.86, *SD*=1.82)	2	.73**	-
	3	.69**	.76**
Applicability	1	-	
(*M*=15.44, *SD*=2.55)	2	.55**	-
	3	.62**	.58**

**Correlation is significant at $p < 0.01$.

4.4 Results

The results of this study are primarily meant to externally validate the tentative mind-set clusters that were proposed in the previous study. This is done by firstly identifying how students' individual attributes, which include their perception of self-efficacy, tolerance for ambiguity, view of own intelligence and preferred learning approaches, relate to their discerning and opportunistic design learning mind-sets (RQ 1). In Section 4.4.1, a Spearman's correlational analysis that tests these inter-relations is discussed. Subsequently, to validate these inter-relations, participants are grouped using a hierarchical cluster analysis, into high surface and low surface learners. Based on previous findings, the two mind-sets are found to prefer different learning approaches (Hamat et al., 2015). The discerning mind-set is associated to higher preference for a deep learning approach i.e., low preference for surface learning approach. In contrast, the opportunistic mind-set is associated to higher preference for a surface learning approach i.e., low preference for deep learning approach. Next, the high surface and low surface clusters are next compared using an Independent T-test. Differences between the two clusters in terms of perceived tolerance for ambiguity, view of own intelligence and self-efficacy are presented. Nevertheless, no differences in terms of the quality of solutions could be observed when participants were grouped based on these self-reported questionnaire data.

In Section 4.4.2, the new clusters of participants that were formed using the scores of their solution quality were used for further analysis. These clusters are expected to be a more reliable source compared to the previous cluster as it comprises behavioural data, and not only on self-reported data. Furthermore, as discussed in Section 4.1, participants that incline toward a discerning mind-set are expected to perform better in a design task than those inclining toward an opportunistic mind-set. To test this proposition, participants were next grouped based on the quality of their solutions. Two new clusters of participants were formed. The first cluster consists of the top 25% participants that achieved the highest scores for in terms of solution quality. The second cluster consists of the bottom 25% participants that achieved the highest scores for in terms of solution quality. Differences between the two clusters in terms of perceived tolerance for ambiguity, view of own intelligence and self-efficacy are presented.

Secondly, the relation between mind-sets and the students' design processes are addressed in Section 4.4.3. The relation between design process and design outcomes is addressed in Section 4.4.4 (RQ 2). This is done by comparing students in the top and bottom 25% of their quality scores, using an Independent T-test. Results of the relation between the two mind-sets and students' design process and design outcomes are described. Thirdly, the effect of design theory-oriented stimuli is addressed in Section 4.4.5. Negligible effects of using reading materials related to design theories towards the quality of solutions generated by the participants are presented.

4.4.1 Individual differences between the two mind-sets: When participants are clustered based on their preferred learning approaches (RQ1)

The Spearman's correlational analysis reveals a strong positive correlation between the fixed view of own intelligence scores to the adoption of surface learning approaches $r(82)=.53$, $p<0.01$. Next, moderate correlations were found between tolerance for ambiguity and the surface learning approach $r(85)=-.38$, $p<0.001$; surface learning approach to the strategic learning approach $r(85)=.31$, $p<0.01$ and between fixed view of own intelligence to self-efficacy $r(74)=.30$, $p<0.05$. Finally, low correlations were found between the strategic learning approach and self-efficacy scores $r(77)=.29$, $p<0.05$; strategic learning approach and fixed view of own intelligence $r(82)=.28$, $p<0.05$; deep learning approach scores to the surface learning approach scores $r(85)=.26$, $p<0.05$; fixed view of own intelligence and tolerance for ambiguity $r(82)=-.25$, $p<0.05$; and tolerance for ambiguity to deep learning approach $r(85)=-.23$, $p<0.05$ (see Table 4.6).

These results indicate that when participants viewed their design capability or intelligence as something that is inbuilt and cannot be changed, they would be likely to incline toward preferring a surface and strategic learning approach. The surface and strategic learning approach items of the survey are associated to concentrating on memorizing information or learning seemingly unrelated bits and pieces of information, in order to pass exams, as well as the need to carefully organize study time. Additionally, these participants indicated higher tolerance for ambiguity related to avoiding confrontations during interpersonal communication; accepting unclear circumstances in problem solving and decision making situations, and lastly feeling unpressured in job-related conditions.

Based on the first three significantly moderate to strong correlations observed, when participants indicated higher surface learning approach scores, they also indicated:

1. Higher fixed view of own intelligence;
2. Higher tolerance for ambiguity;
3. Higher strategic learning approach.

These results indicate that when participants viewed their design capability or intelligence as something that is inbuilt and cannot be changed, they would be likely to incline toward preferring a surface and strategic learning approach. The surface and strategic learning approach items of the survey are associated to concentrating on memorizing information or learning seemingly unrelated bits and pieces of information, in order to pass exams, as well as the need to carefully organize study time. Additionally, these participants indicated higher tolerance for ambiguity related to avoiding confrontations during interpersonal communication; accepting unclear circumstances in problem solving and decision making situations, and lastly feeling unpressured in job-related conditions.

Table 4.6 Spearman's correlations between fixed view of own intelligence, preferred learning approaches, tolerance for ambiguity and self-efficacy

	1 Fixed VI	2 Deep LA	3 Surface LA	4 Strategic LA	5 TA
1. Fixed view of own intelligence	—				
2. Deep LA	.20	—			
3. Surface LA	.53**	.26*	—		
4. Strategic LA	.28*	.13	.31**	—	
5. Tolerance for ambiguity	–.25*	–.23*	–.38***	–.21	—
6. Self-efficacy	.30*	.09	.22	.29*	–.04

*Correlation is significant at $p < 0.05$.
**Correlation is significant at $p < 0.01$.
***Correlation is significant at $p < 0.001$.

A hierarchical cluster analysis (SPSS) using the *Between-Groups Linkage* and *Squared Euclidean Distance* method (Field, 2013) was used to group students into low and high surface learners. This means that participants who scored themselves higher on the surface learning approach scale are grouped into the high surface cluster, and participants who scored lower on the surface learning approach scale are grouped into the low surface cluster. With reference to the types of design learning mind-sets proposed in the previous chapter, these two groups are comparable to the discerning (low surface) and opportunistic (high surface) mind-set types. These two groups of students were compared using an Independent T-test.

The learning approach that they preferred, their view of their own intelligence, their perceived level of self-efficacy and their tolerance for ambiguity were compared. The two groups comprised of 43 participants in the low surface and 36 participants in the high surface clusters (see Table 4.7). The mean scores of the surface learning approach scale was compared to assess the relevance of the two clusters. The surface learning approach scores were significantly lower for the low surface (M=7.7, SD=1.5) as compared to the high surface (M=11.5, SD=1.5) cluster; $t(77)$=-11.0, p=0.000.

The strategic learning approach scores were significantly lower for the low surface (M=6.2, SD=1.5) as compared to the high surface (M=7.1, SD=1.9) cluster; $t(77)$=-2.4, p=0.020. This indicates that high surface learners would be more likely to adopt the strategic learning approach. With respect to the deep learning approach, the independent T-test did not reveal any significant differences between the low surface (M=8.1, SD=1.0) and high surface (M=8.2, SD=0.9) clusters; $t(77)$=-0.5, p=0.642.

Table 4.7 Comparison between participants in the low surface and high surface clusters

	Cluster 1: Low Surface N=43	Cluster 2: High Surface N=36	Effect size, Cohen's D
Deep LA	8.1	8.2	0.11
Surface LA* **	7.7	11.5	2.53
Strategic LA*	6.2	7.1	0.53
Fixed View of own intelligence **	5.2	6.7	0.77
Self-efficacy*	5.2	6.0	0.53
Tolerance for ambiguity**	40.3	35.4	0.75

*T-test on average scores over two clusters was significant at p<0.05.
**T-test on average scores over two clusters was significant at p<0.01.
***T-test on average scores over two clusters was significant at p<0.001.

The fixed view of own intelligence between the high and low surface clusters were also compared. The Independent T-test indicates that the fixed view of own intelligence scores were significantly lower within the low surface (*M*=5.2, *SD*=1.8) compared to the high surface (*M*=6.7, *SD*=2.1) cluster; *t*(74)=3.4, *p*=0.001. Subsequently, scores of tolerance for ambiguity and self-efficacy were compared. In the low surface cluster (*M*=40.3, *SD*=6.1), the tolerance for ambiguity scores were significantly higher compared to the high surface cluster (*M*=35.4, *SD*=6.9); *t*(77)=3.3, *p*=0.001. With regards to self-rates of design learning performance, participants in the low surface cluster rated themselves significantly lower (*M*=5.2, *SD*=1.4) as compared to the high surface (*M*=6.0, *SD*=1.6) cluster; *t*(69)=-2.3, *p*=0.023. Notably, the independent T-test reveals that:

1. Participants in the high surface cluster are more tolerant towards ambiguity and would rate their self-efficacy higher.

2. Participants in the low surface cluster are less tolerant of ambiguity and would rate their self-efficacy lower.

4.4.2 Individual differences between the two mind-sets: When participants are clustered based on the quality of their solutions (RQ1)

This Independent T-test reveals several significant differences between participants in the bottom and top 25% clusters (see Table 4.8). Participants in the bottom 25% cluster had significantly lower mean scores (*M*=10.03, *SD*=1.83) compared to participants in the top 25% cluster (*M*=14.41, *SD*=2.36); *t*(29.28)=-.05, *p*<0.001. Their lowest scores (*M*=8.61, *SD*=2.33) were also significantly lower compared to participants in the top 25% cluster (*M*=10.70, *SD*=4.03); *t*(44)=-2.15, *p*<0.05. Furthermore, their highest scores (*M*=11.43, *SD*=1.88) were significantly lower compared to participants in the top 25% cluster (*M*=18.65, *SD*=0.78); *t*(44)=-17.03, *p*<0.001. The effect sizes of the mean scores, lowest scores and highest scores were relatively big. This is especially so with regards to the mean scores and highest scores that participants achieved. The sample effect sizes contain values of Cohen's *d* that are larger than 2.0. This indicates that exceptionally large differences between the two clusters, in terms of their mean scores and highest scores (see last right column of items 13 to 15 in Table 4.8

Solutions produced by participants in the bottom 25% cluster scored significantly lower in terms of *relevance* and *specificity*. In terms of *relevance*, the *applicability* (*M*=2.36, *SD*=0.65) and *effectiveness* (*M*=2.03, *SD*=0.41) of their solutions were lower compared to the *applicability* (*M*=3.80, *SD*=0.60); *t*(44)=-7.76, *p*<0.001, and

Table 4.8 Differences between top 25% and bottom 25% scoring students on the three different levels

Item/Scale	Cluster 1: Bottom 25% N=23	Cluster 2: Top 25% N=23	Effect size, Cohen's D
Presage level variables			
Items on tolerance for ambiguity			
1. It really disturbs me when I am unable to follow another person's flow of thought. (interpersonal communication) *	3.04	3.74	0.46
2. A group meeting functions best with a definite agenda. (Problem solving) *	4.35	3.87	0.62
Item on Self-efficacy			
3. Finally, can you please indicate how you scored on your design work, so far? *	5.90	4.90	0.71
Process level variables			
4. Low level questions (LLQ) **	0.48	0.83	0.77
5. Generative design questions (GDQ) *	0.17	0.00	0.62
6. Faced difficulties *	1.04	0.83	0.70
Product level (outcome) variables			
7. Relevance *	25.06	29.45	1.20
8. Specificity **	25.11	36.35	1.83
9. Mean: Applicability ***	2.36	3.80	2.29
10. Mean: Effectiveness ***	2.03	3.01	1.68
11. Mean: Completeness ***	2.85	3.63	1.03
12. Mean: Implicational Effectiveness ***	2.79	4.00	1.26
13. Mean score of all solutions generated by student ***	10.03	14.41	2.08
14. Solution with lowest score generated by student *	8.61	10.70	0.63
15. Solution with highest score generated by student ***	11.43	18.65	5.02

*T-test on average scores over two clusters was significant at $p<0.05$.
**T-test on average scores over two clusters was significant at $p<0.01$.
***T-test on average scores over two clusters was significant at $p<0.001$.

effectiveness (M=3.01, SD=0.72); $t(44)=-5.70$, $p<0.001$ of participants in the top 25% cluster. In terms of *specificity*, the *completeness* (M=2.85, SD=0.83) and *implicational effectiveness* (M=2.79, SD=1.09) of their solutions were lower compared to the *completeness* (M=3.63, SD=0.66); $t(44)=-3.51$, $p<0.001$ and *implicational effectiveness* (M=4.00, SD=0.82); $t(44)=-4.26$, $p<0.001$ of solutions produced by participants in the top 25% cluster. This means that participants in the top 25% cluster were able to generate solutions that were more *relevant* and *specific*. In terms of *relevance*, this means that their solutions are more applicable and effective. In other words, their solutions apply more clearly to the stated problem and solves the problem to a better degree. In terms of *specificity*, this means that the completeness and implicational effectiveness of their solutions are higher. To put it differently, their solutions covered more independent sub-components with regard to who, what, where, when, why, and how. Additionally, their solutions clearly conveys their recommended action to the expected outcome.

In terms of individual differences, observations related to tolerance for ambiguity and self-efficacy can be found. Firstly, with regards to their *tolerance for ambiguity,* participants in the bottom 25% cluster showed significantly lower scores for an item related to *interpersonal communication* (M=3.04, SD=1.11) as compared to participants in the top 25% cluster (M=3.74, SD=0.96), $t(44)=-2.2$, $p<0.05$. On the other hand, participants in the bottom 25% cluster showed significantly higher scores (M=4.34, SD=0.78) on an item related to problem solving as compared to students in the top 25% (M=3.87, SD=0.76); $t(44)=2.12$, $p<0.05$. Medium to high effect sizes can be observed for these two items at Cohen's d=0.46 and 0.62 respectively.

This means that participants in the bottom 25% cluster tolerate ambiguity with regards to interpersonal communication better than they do compared to situations related to problem solving. More precisely, they prefer to have a definitive agenda when involved in group meetings as they are less tolerant of ambiguity in this situation. However, they perceive that it is less important for them to be able to follow another person's trail of thought, as compared to participants in the top 25%, as they are more tolerant of ambiguity in this type of situation. Secondly, participants in the bottom 25% cluster showed significantly higher self-efficacy scores (M=5.90, SD=1.44) as compared to the top 25% (M=4.90, SD=1.37); $t(39)=2.28$, $p< 0.05$. This means that although they indicated higher self-rates on their own previous design works, i.e., they are optimistic of their previous design performance, they actually produced solutions that are of lower quality compared to students in the top 25%.

4.4.3 Influence of mind-sets on question-asking strategies and perception of difficulties faced throughout design process (RQ2)

In terms of design process, it could be observed that participants in the bottom 25% cluster, that are representative of participants that incline toward the opportunistic mind-set, asked significantly fewer low-level questions (M=0.48, SD=0.51) as compared to students in the top 25% (M=0.83, SD=0.39); $t(23)$=-2.60, p<0.05, that are representative of participants that incline toward the discerning mind-set. Moreover, they asked significantly more generative design questions (M=0.17, SD=0.51) as compared to students in the top 25% (M=0.00, SD=0.39); $t(23)$=2.15, p<0.05 (see also Table 4.8). In addition, participants in the bottom 25% cluster showed that they faced significantly more difficulties (M=1.04, SD=0.21) compared to participants in the top 25% cluster (M=0.83, SD=0.39); $t(23)$=2.37, p<0.05. Relatively strong effect sizes, Cohen's d=0.77, 0.62 and 0.70 can be founded for these three observations respectively. These strong effect sizes illustrate the large differences between the two clusters in relation to the types of questions they asked and perceived difficulties that they faced throughout their engagement in the design task.

4.4.4 Relation between design process and design outcomes (RQ2)

The relationship between the types of questions that students asked and quality of their solutions were tested using the Chi^2 test. Questions were categorised as either low level, high level or generative design questions. The quality of students' solutions were categorised as either "high" or "medium and low". The results indicated that such a statistically significant relationship exists between the quality of students' solution and the type of low level questions that they asked ($x^2(1)$=9.052, p<0.01, n=91). An inspection of the standardized residuals reveal that as students asked more low level questions, the quality of solutions that they produced also increased. Additionally, it reveals that when students did not ask low level questions, the quality of solutions they produced were not likely to be of high quality (see Appendix P for table of Chi^2 test). No relationships between the high and generative design questions to the quality of outcomes can be observed.

4.4.5 Effect of design theory-oriented stimuli (RQ3)

The relationship between the quality of students' solutions and whether they received the hand-out related to design theories was also examined with a Chi^2 test. However, no statistically significant relationship can be found ($x^2(2)$=1.667, p>0.005, n=91). This means that the related design theories that students read did not have any effect on the quality of their solutions (see Appendix P for table of Chi^2 tests).

4.4.6 Summary of findings

The interaction between individual differences, design process and quality of design solutions are summarised in Figure 4.4. Attributes on the presage level that are associated to participants in the discerning mind-set cluster are positively related to the quality of solutions that they produce. This shows that participants in the discerning mind-set cluster displayed the capability to produce higher quality solutions. Results indicate that participants in the discerning mind-set cluster showed higher tolerance for ambiguity in problem solving situations, but not in interpersonal situations. They also associated themselves to lower levels of self-efficacy. Additionally, questions that they queried regarding the task inclined toward low level questions. In contrast, participants in the opportunistic mind-set cluster are associated to a contrasting set of attributes. These attributes include indicating a higher tolerance for ambiguity in situations that are related to interpersonal situations, and not in problem solving situations. Furthermore, they perceive themselves as having higher self-efficacy compared to their counterparts. Further evidence related to differences in terms of engagement in the design process can be observed.

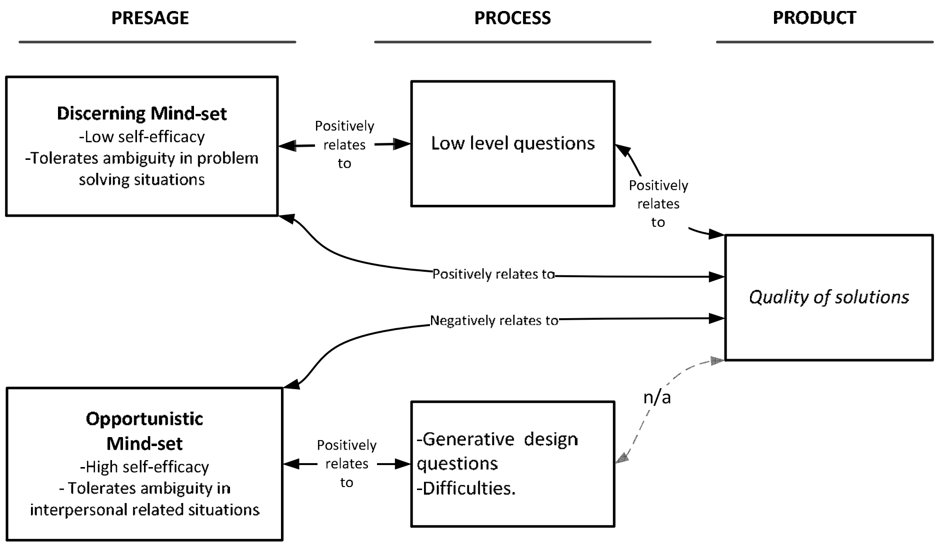

Figure 4.4 Connections between variables on the three different levels of the 3P model

Participants inclining toward an opportunistic mind-set implied that they faced difficulties throughout completing the design problem. Furthermore, they posed more generative design questions compared to participants in the discerning mind-set cluster. However, there was no evidence to indicate that asking generative design questions was positively or negatively related to the quality of their solutions.

Conversely, low level questions are positively correlated to the quality of solutions produced, and participants in the discerning mind-set cluster are associated to asking these low level questions. Attributes connected to the opportunistic mind-set type have been found to be associated with lower quality solutions. That is, high self-efficacy and tolerance for ambiguity in interpersonal related situations are negatively related to the quality of solutions that participants produce. This provides evidence that students would be more likely to produce solutions with lower quality. In this study this means that their solutions scored lower in terms of relevance and specificity.

4.5 Discussion and Conclusion

Distinct differences between the opportunistic and discerning mind-sets have been found in this study. These differences can be found across all three presage, process and product levels of the 3P model. These differences are discussed in the subsequent sub-sections.

4.5.1 Mind-sets and individual differences in design learning

The first research question in this study was formulated to test "how individual attributes that include perception of *self-efficacy*, *tolerance for ambiguity*, *view of own intelligence* and *preferred learning approaches* relate to the discerning and opportunistic design learning mind-sets". With regards to preferred learning approaches, the opportunistic mind-set cluster was found to be closely linked to high surface and strategic learning approaches. Students in the discerning mind-set cluster, however, indicated a significantly lower preference for the surface learning approach.

No statistical significance related to the deep learning approach can be observed. The design students scored equally high on the deep learning approach scale when grouped in the discerning mind-set (M=8.1, SD=1.0) and opportunistic mind-set (M=8.2, SD=0.9) clusters. It can be anticipated that students who have managed to be enrolled in the university (i.e. tertiary education) would indeed display high levels of analytical reasoning, which are closely associated to the deep learning approach. A high or low indication of preference for a surface learning approach becomes a key variable to differentiate the two mind-set types. These results are consistent with and further support the findings from the previous study, presented in Chapter 3. In other words, the assessment of preference towards the surface learning approach proves a more suitable measure to identify the discerning or opportunistic mind-set types.

Previous studies have shown that the deep learning approach is negatively correlated to a fixed view of own intelligence (Dahl et al., 2005; Stump et al., 2009) and positively correlated to a growth view of own intelligence (Stump et al., 2009). However, significant correlations between a fixed view of own intelligence to the surface learning approach could not be found. In this study however, it was discovered that the adoption of high surface learning approaches are indeed related to the fixed view of own intelligence (see Section 4.4.1). The correlations and Independent T-test indicate that design students that viewed their own intelligence and design capabilities as an unchangeable trait, indicated a high preference for the surface learning approach. On the other hand, design students that viewed their own intelligence and design capabilities as a developable and changeable trait indicated a low preference for the surface learning approach. This strongly suggest that design students that incline toward an opportunistic mind-set would also tend to have a fixed view of their own intelligence and design capabilities. On the other hand, design students that incline toward a discerning mind-set would not view that their intelligence and design capabilities are a fixed and unchangeable trait.

Students in the opportunistic mind-set cluster showed higher tolerance for ambiguity and higher self-efficacy scores (see Independent T-test in Section 4.4.1). In terms of tolerance for ambiguity, this indicates that the opportunistic mind-set student would avoid confrontations during inter-personal communication, accept unclear circumstances in problem solving and decision making situations; and feel unpressured in job-related conditions. This is in contrast to the discerning mind-set students who showed low tolerance for the same abovementioned situation. In a problem solving or design based situation, it is highly likely that a tolerance for such a situation would impede the seamless course of the project. This is especially so when ambiguous or uncertain conditions that need to be clarified are left unattended. Furthermore, individuals with a low tolerance for ambiguity tend to avoid ambiguous stimuli (Furnham & Ribchester, 1995). Similar findings can be observed in the subsequent analysis (see Independent T-test in Section 4.4.2), when students were clustered in terms of the quality of their outcomes. Two items were statistically significant. The opportunistic mind-set cluster indicated through these items that they would tolerate not being unable to follow another person's flow of thought. However, they indicated that they would have low tolerance in problem solving situations. More specifically, they would not be able to tolerate having meetings without a definitive agenda.

Students in the discerning mind-set cluster indicated adverse preferences for the two items. This suggests that, firstly, students that incline toward a discerning mind-set would be more likely to avoid ambiguous conditions by clarifying the situation i.e., possibly by facing confrontations during interpersonal communication in order to avoid the ambiguity. Secondly, as these students are able to tolerate ambiguity in a problem solving situation, this also indicates that they would be able to flexibly adapt and better manage within problem solving situations. On the other hand, students inclining toward an opportunistic mind-set would be less analytical in a design or problem solving situation. They would also be less likely to engage in interpersonal confrontations to communicate any impending ambiguities.

The design process is however an iterative logical process that is realized by different modes of reasoning (Takeda et al., 1990) i.e., throughout the different stages of design, different modes of reasoning are required. Thus, in an idea generating phase where creativity and judgements should be deferred, a high tolerance for ambiguity is highly likely to be of value. It can then be anticipated that opportunistic mind-set students would fare better in this stage of the design process. However, it might prove to be a disadvantageous attribute to adopt in a detail design phase where higher analytical modes of reasoning are required. It is however necessary for students to have tolerance for ambiguity as the process of designing in itself is highly associated to complex and wicked problems i.e., problems that are not well-defined and are subject to various re-interpretations (Buchanan, 1992; Coyne, 2005). Ultimately, design students will be and are required to deal with ambiguity.

In terms of higher self-efficacy scores associated to the opportunistic mind-set cluster, this demonstrates that these design students are able to regulate their coping behaviours (Bandura, 1982) when dealing with complexities associated to design learning that require high reasoning capabilities. In this study, significant correlations between students' surface and strategic learning approach scores could be observed. This indicates that opportunistic mind-set students are highly likely to cope by organizing their time and learning activities towards memorizing information and fulfilling course requirements.

It is propagated that students who formulate high expectations about their prior performance do perform better (Bandura, 1982; Miller et al., 1996; Pintrich & de Groot, 1990; Grant & Dweck, 2003; Richardson, et al., 2012), however, this is not the case in this study. Design students who had showed higher levels of self-efficacy generated solutions that were of lower quality. Their solutions were less relevant and specific to the problem given. Coupled with their inclinations towards surface learning approaches (e.g., unrelated memorising, being bounded to syllabus and not being able to connect knowledge, concepts or information), it is possible that these students are actually unaware of the complex reasoning processes that are required of them. On the other hand, discerning mind-set students had showed lower levels of self-efficacy, although they had generated better quality solutions. This finding supports the notion that lower levels of self-efficacy can result in better performance (Christensen et al., 2002). However, it can be expected that this situation occurs only when students adopt self-regulatory behaviours, such as consciously contemplating and controlling the processes involved in their learning activities (McLaughlin, 1990).

4.5.2 Question formulations, design theory-oriented stimuli and quality of solutions

The second research question in this study addresses how the design process that students engage in and the quality of design solutions they produce relate to the two mind-sets. The discerning mind-set cluster of design students asked more low level questions, while opportunistic mind-set students asked more generative design questions. More notably, it was statistically significant that students inclining toward the opportunistic mind-set, rarely asked low level questions compared to their counterparts. No significant differences could be observed between these two clusters of design students with regards to the high level questions that they asked. The amount of high level questions for both opportunistic and discerning mind-set students were comparable. It has been recommended that the process of question asking be sequentially ordered from low level to high level and generative design questions in order to establish more reliable forms of knowledge (Dillon, 1984; Eris, 2002).

This is clearly evident in the high quality of solutions that are generated by discerning mind-set students. These students asked significantly more low level questions. In other words, students that incline toward a discerning mind-set did not jump to generative design questions without establishing a strong foundation of the design problem through low level questions first. On the other hand, students inclining toward an opportunistic mind-set jumped to generative design questions without formulating such lower level questions. However, no statistically significant results can be reported with regards to generative design questions to the quality of solutions.

The third research question in this study was formulated to test whether "the quality of students' design outputs be improved by introducing design theory-oriented stimuli". The results (see Section 4.4.5) clearly indicate that the stimuli did not have any notable effect on the quality of design solutions that students produced. Important to keep in mind is the short amount of time that was allocated for the design task. Thus it may be challenging to expect immediate and noticeable effects on the solutions that are produced in terms of quality. Possibly, students need to internalize and make sense of the design theories presented, before they can apply the design theories to their design process.

4.5.3 Recommendations and Limitations

Findings from this study provide potential implications for design education. Most importantly, design students should be made aware of their individual dispositions that exist prior to engagement in learning. These factors influence the way they engage in learning and the outcomes of their learning. These dispositions include their mind-sets, perception of self-efficacy, view of own intelligence, tolerance for ambiguity and preference of learning approach. Secondly, students should be motivated and be taught ways of managing and harnessing their individual dispositions. This includes developing their mind-sets towards a more discerning learning mind-set, and motivating them to view their own intelligence and capabilities as a developable trait, as opposed to a fixed trait that cannot be changed. Students should also be made aware of their own levels of self-efficacy so that they can regulate their own learning activities. Furthermore, students can also be made aware of the ambiguity in solving design problems and be trained as to how to manage these situations. Design students should also be taught about the types and strategies of formulating questions. Questions that are better structured can establish more reliable forms of knowledge. Besides, it also enables students to better understand the design problems they engage in and enables them to formulate imminent actions. These notions may possibly extend to designers, as a better understanding of the design problems that they attempt to solve is also essential in producing more applicable, relevant and possibly, even novel solutions.

Results obtained in this study are derived from an experimental situation and there are limitations to generalising these results to the actual design studio setting (Cohen et al., 2007). Although it would be expected that these results can be collectively attributed to design students from similar backgrounds or training, such an estimation should be cautiously attempted due to the limitations of the sampling method that was used (see Section 4). Apart from that, data was gathered at only a single point in time, thus process data were not available in this study. Participants were not informed to reflect on specific phases of their design process during the data collection sessions. The learning approaches adopted by the participants throughout or at specific points of the complex design process could not be fully captured. Still, the information obtained was very rich and allowed detailed analysis which raises confidence in the findings.

Future studies should take into consideration the possibility of isolating distinctly different parts of the design process. The types of activities that a student engages in when he or she is in a conceptual design phase differs as compared to when they are engaging in a detailed design phase. These different activities require different mind-sets, levels of tolerance toward ambiguity etc. By differentiating the distinct parts of the design process, a clearer delineation of students' design learning is possible through comparisons between the different phases. Additionally, the method of intervention that was used in this study did not yield any differences toward the quality of solutions that were produced. Other methods of intervention should be taken into consideration. For example, this study has shown that the different types of questions that students asked possibly yield different quality in terms of the design outcomes. Could this be a way to induce reflection within students? If students are stimulated with deeper reasoning questions, will they engage in design activities that would lead them to create solutions with better design quality? In the following Chapter, this method of intervention is investigated next to distinguishing the design phases that students engage in throughout their design process.

5

The effects of mind-sets in designing

In the previous chapter, the discerning and opportunistic mind-sets that exist within design students were externally validated. Differences between design students inclining toward the discerning and opportunistic mind-sets, on the three presage-process-product levels of Biggs's (1993) 3P model were found. On the presage level, students' tolerance for ambiguity and perceived self-efficacy were found to differ. On the process level, the types of questions that students asked were different. On the product level, the quality of solutions that they produced were also different. However, the design–oriented stimuli that was used in the previous research study did not yield any results. Subsequently, a third research study with improved study design was undertaken to further test the two mind-sets. The results of this study are presented in this chapter. A new design problem and intervention was incorporated into this study. Additionally, better behavioural data were collected. Design students were asked to fill in a questionnaire and solve a design problem. In the questionnaire, 22-items were specifically developed, based on the characteristics identified from the prior two studies, to assess students' mind-sets. Additionally, a reflection-oriented stimuli was used for the intervention, to test whether the design activities and design outputs produced by design students that incline toward the two different mind-sets, could improve. By analysing students' design activities, different approaches of the two mind-sets when engaging in a design task can be observed. Differences in the quality of design solutions produced by students inclining toward the two different mind-sets can also be observed. Insights obtained from this study allow to the derivation of recommendations on how to potentially support design teaching and learning.

5.1 Research aims, hypotheses and questions

The primary aim of this empirical study was to expand upon current understanding of the two mind-sets and its effect on design behaviour and outcomes. This expansion is undertaken by testing the differences between the discerning and opportunistic mind-sets on their learning approach, design processes and quality of outcomes of their design work. It is hypothesised that the two mind-sets can influence the approach that students prefer to adopt and the external behavioural responses that they would choose to apply in learning. Furthermore, these predispositions are expected to influence the quality of outcomes that the design students produce. Findings from the two previous studies have indicated that deep learning approaches are closely connected to the discerning mind-set, while surface learning approaches are connected to the opportunistic mind-set (see Chapters 3 and 4). Based on these findings, these learning approaches are also expected to influence the design activities that students engage in along with the quality of design solutions that students produce.

Designing requires interaction with unclear, inexplicit and ambiguous problem solving situations that are also complex, non-routine and ill-defined (Dorst & Cross, 2001; Lawson, 2006). In the context of a complicated design task, students inclining toward a discerning mind-set are expected to deeply engage with the design problem. This includes seeking meaning between concepts, relating ideas and information, and using corroborative evidence to support the development of design ideas and/or decisions. It is also expected that discerning mind-set students will engage in comprehensive design activities and that they will thoroughly consider the aspects of a design problem. Furthermore, discerning mind-set students are expected to make more comprehensive considerations when engaged in a design problem compared to the opportunistic mind-set students. In contrast, students inclining toward an opportunistic mind-set are expected to take convenient measures and not delve as deeply into design tasks at hand. They are expected to contrive upon more convenient strategies that are easily accessible, and avoid undesirable or difficult situations. This includes engaging in design tasks at a surface level and making superficial connections with non-corroborative evidence (Hamat et al., 2015; Hamat et al., 2016).

In this study, students that incline toward the discerning and opportunistic mind-sets are expected to considerably differ in terms of their engagement in their design processes. This is tested by introducing an element of ambiguity in the experiment. Students were asked to redesign their local national zoo where they are required to engage in contemplating large spatial areas on a macro-level. Being trained as product designers, these students are more familiar with designing on a micro scale. Thus, their behaviour when engaged in solving an unfamiliar design problem can be compared when they incline toward a discerning or opportunistic mind-set. It is expected that students inclining toward a discerning mind-set will engage in deeper reasoning with the design problem, even though it is unfamiliar. They would thus consider the problem more comprehensively. As aspects related to a design problem are considered more comprehensively, the quality of solutions that design students produce are also expected to increase. Hence students inclining toward a discerning mind-set are expected to produce solutions with better quality. This is in concurrence with other studies on mind-sets where mediating behavioural variables were found to affect outcomes (Armor & Taylor, 2003; Burnette et al., 2013; Zeng et al., 2016).

Based on the prior discussions, this study aims to answer the following research questions:

1. Do opportunistic and discerning mind-set students prefer to approach their learning differently?

2. What is the relationship between students' design processes and the quality of design solutions they produce?

Outcomes are assessed by evaluating the creativity of design solutions produced by students. A creative solution is defined as a solution that is of high quality and is novel (Dean et al., 2006). A high quality solution is a solution that is effective, implementable and applies to the problem at hand, while a novel solution is a unique and uncommon solution compared to the overall population of solutions (Dean et al., 2006). The creativity of solutions produced by students are assessed for its quality in terms of *clarity, completeness, usefulness,* and *feasibility*; and its novelty in terms of *originality* (see Section 5.2.3 for full description of scales). Therefore as students incline toward a discerning mind-set, they are expected to produce more clear, complete, useful, feasible and original design solutions.

The quality of solutions produced by students is expected to increase when they engage in deeper modes of reasoning. One way to create deeper reasoning is by presenting reflection-oriented stimuli (Dym et al., 2001). By stimulating the students with deep reasoning questions, it is expected that students would engage in design activities that leads to better quality design solutions. To stimulate reflection and deeper modes of reasoning, questions related to the design problems are posed to students in the experimental group. It is anticipated that students will engage more actively i.e., reflect more deeply with the design problem when questions related to the design problem are posed to them. It is anticipated, however, that this increase will be more apparent within discerning mind-set students as compared to opportunistic mind-set students. This is because students that incline toward the discerning mind-set prefer deep learning approaches. Additionally, their question-asking strategy and low tolerance for ambiguity indicates that they are more likely to clarify and avoid ambiguous situations (see Section 4.5.1 and 4.5.2).

Based on the prior discussions, this study also aims to answer the following research questions:

3. What is the inter-relation between the two mind-sets and the design processes that they engage in? Furthermore, are there differences between discerning and opportunistic mind-set students, in terms of their design processes, when they are introduced to reflection-oriented stimuli?

4. What is the inter-relation between the two mind-sets and the quality of design solutions that they produce? Furthermore, does the quality of design solutions differ between discerning and opportunistic mind-set students when they are introduced to reflection-oriented stimuli?

An adapted version of Biggs's (1993) 3P model is used as a conceptual framework to test the abovementioned research questions and speculated hypotheses (see Chapter 2). The conceptual framework for this research study is presented in the following section.

5.2 Conceptual framework

The 3P model provides a general framework to test the research questions and hypotheses formulated (see Figure 5.1). The model consists of three different levels: the *presage*, *process* and *product levels.* The research questions and hypotheses formulated tests the distinct variables and its inter-relations on these three levels.

The first research question is related to whether opportunistic and discerning mind-set students prefer to approach their learning differently. To examine this question, variables within the *presage level* are tested. The second research question relates to examining the inter-relation between the two mind-sets and the design processes that they engage in, and further, the inter-relations when students are introduced to reflection-oriented stimuli. To examine this question, interactions between the two mind-sets, as variables on the *presage level*, and design processes that students engage in, as variables on the *process level*, are tested.

The third research question concerns the inter-relation between students' design processes and the creativity of design solutions they produce. This question requires the testing of interactions between the variables on the *process level* and *product level.* Finally, the fourth research question is related to the inter-relation of the two mind-sets and the creativity of design solutions that they produce, and further, the inter-relations when students are introduced to reflection-oriented stimuli. To examine this question, mind-sets on the *presage level* are tested against variables on the *product level*. The description of each variable on the different levels are discussed in the following sub-sections.

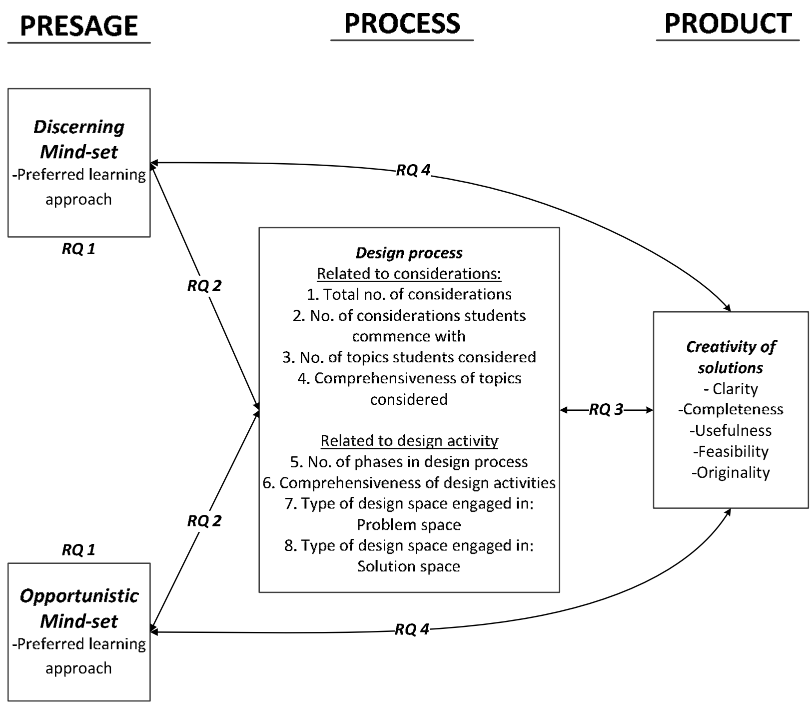

Figure 5.1 Variables in the adapted "3P" model of students' learning used in this research study

5.2.1 Variables on the presage level

Variables within students that "exist prior to actual engagement in learning" (Biggs, 1993, p. 8) are situated in the *presage level*. Two variables assumed to be prevalent within students are focussed upon in this study. These encompass *mind-sets* and the *learning approaches* that students would prefer to adopt. As discussed in Chapters 2 and 3, the mind-sets are categorised as either discerning or opportunistic. As for the learning approaches, three types of learning approaches that students prefer are assessed. This includes their preference for deep, strategic or surface approaches in learning design (see section 2.3.2 in Chapter 2).

5.2.2 Variables on the process level

In total, eight variables are situated at the *process level*. Out of the eight variables, the first four are related to the considerations that students take into account and the remaining four are related to the design activities that students engage in when designing. To obtain insights regarding the considerations that students took into account, four variables were assessed.

Firstly, the number of considerations that students made were tallied throughout all the design activities that students engaged in prior to working on their design solutions. Secondly, the number of considerations that students made in their very first design activity were tallied. By assessing students' considerations in these two instances i.e., in total and in the beginning, an idea of the breadth of students' considerations throughout and in the earlier part of their design process can be obtained. Thirdly, the number of *specialised topics* that related to the design task which students considered were tallied. Specialised topics that students considered include the *safety of guardians; feeding of animals; facilities of zoo; and climate.* Fourthly, the comprehensiveness of students' considerations in regard to these specialised topics are assessed.

The remaining four variables are assessed to obtain insights regarding the design activities that students engaged in. Firstly, the number of *phases* that students go through during their entire design process is assessed. These phases account for the different design activities that they engage in, in a sequential manner. These design phases are very well-aligned with the existing phases of the design process (Howard et al., 2008; Lawson, 2006). The phases that students engaged in include *exploring problems; identifying connections;* and *proposing solution* etc. (see Table 5.1). Next, the comprehensiveness of the design activities within these phases are assessed. These two variables shed light on the breadth and depth of design activities students immerse themselves in. In general, some students direct their attention towards the problem space, while others spend more time in the solution space. However, in some cases, there are also students who direct their attention equally to both the problem and solution spaces. The seventh and eight process variables are related to assessing the number of design activities that students engaged in which are related to the problem and solution space respectively (see Section 5.3.7).

5.2.3 Variables on the product level

The creativity of solutions generated by students is assessed on the *product level* of the 3P model. Creativity here means that a solution has both quality and novelty (Dean et al., 2006) (see Section 5.1 for descriptions of quality and novelty). The creativity of solutions produced by students is assessed on five sub-scales: *clarity*, *completeness, usefulness, feasibility* and *originality*. These sub-scales are the outcome of adaptations based on Dean et al's. (2006) scales for idea evaluation. These adaptations were made to the original scales based on discussions with a design teacher from the Industrial Design Engineering faculty of TU Delft. This teacher was a course co-ordinator for one of the undergraduate design programme with approximately nine years of experience in co-ordinating design courses. The creativity scales along with the outputs produced by students were reviewed by this teacher. These scales were refined based on feedback received from this discussion (see Table 5.1).

The first and second scales are related to *clarity* and *completeness* respectively. *Clarity* refers to the degree to which the solution is communicated well. In this study, c*larity* is rated highly when the solution is easily understood by the evaluator. This includes clarity in terms of grammar and word usage, and clarity of the solution idea that is being conveyed. The second scale is related to *completeness*. *Completeness* refers to the degree to which the solution will thoroughly solve the problem. When an evaluator rates a solution as more complete, this means that he perceives the solution as solving a bigger part of the problem posed. This encompasses the number of independent sub-components into which the solution can be decomposed. This includes the breadth of coverage with regards to who, what, where, when, why, and how the solution solves the design problem.

Table 5.1 Definition of creativity scales used in this study

Creativity scale	Definition
Clarity	The degree to which the solution is communicated well.
Completeness	The degree to which the solution will thoroughly solve the problem.
Usefulness	The degree to which the solution benefits the stakeholders involved (the animals, the guardians and visitors)
Feasibility	The degree to which the solution can easily be produced/implemented (in terms of manufacturing, technology and existing facilities)
Originality	The degree to which the solution is rare, completely new and surprising (among other solutions produced).

The third scale is related to the *usefulness* of the solution that students produce. *Usefulness* refers to the degree which the solution benefits the stakeholders involved. Solutions are considered more useful when more advantages for the stakeholders arise. Positive correlations between these three scales have previously been reported (Dean et al., 2006). Based on these results, positive correlations between the *clarity* and *completeness* to the *usefulness* of solutions can be anticipated in this study. The fourth scale is related to the *feasibility* of solutions. *Feasibility* refers to the degree which the solution can be easily produced and implemented. Solutions are considered as less feasible when the level of difficulty to implement the solution increases.

The fifth and last scale is related the *originality* of solutions. *Originality* refers to the degree to which the solution is rare, completely new and surprising. The originality of the solution is compared between the solutions that are produced within the sample students. Solutions are considered more original when they are unexpected and surprising. Studies have shown that the *feasibility* of solutions are negatively correlated to *novelty* (Dean et al., 2006). In other words, as a solution is more original or breaks convention, the solution will be more difficult to be actualized. This means that the *originality* of solutions can be expected to negatively correlate to *feasibility* in this study.

5.3 Methods

A quasi-experimental study with control group design was chosen for this study (Kumar, 2011). The control group design allows for two different conditions to be tested within the respondents. One group of respondents was presented with reflection-oriented stimuli (experimental group) while the other group of respondents was not (control group). Before the actual design task, respondents filled in a first questionnaire to assess their learning approaches and mind-sets in design learning. They were next given a design task to redesign their local national zoo. Subsequently, they filled in a second questionnaire after they engaged in the design task (see Figure 5.2). The second questionnaire was related to their perception of the design task.

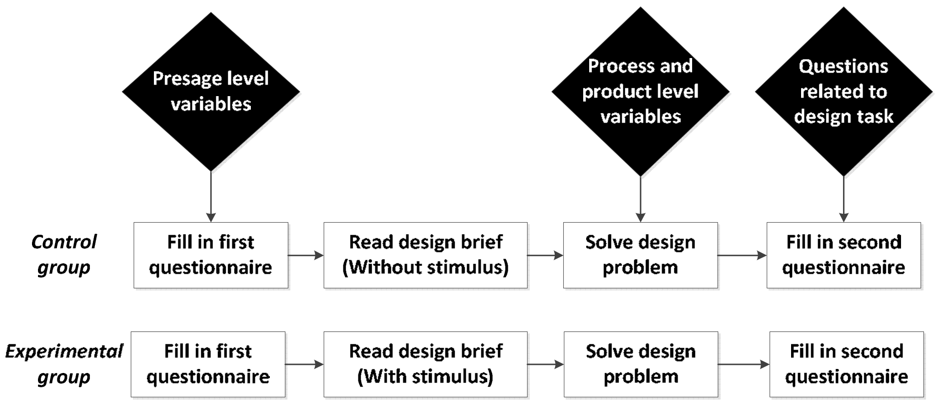

Figure 5.2 Experiment procedure for control and experimental groups

5.3.1 Participants

45 respondents from a public university in Malaysia voluntarily participated for the study. They received a book voucher at the end of the experiment as an incentive and compensation for their participation. 25 respondents were enrolled in the second year of their education while the remaining 20 were enrolled in the third year of their study. 20 of them were male and 25 were female. 91.1% of the respondents were

between 21 and 23 years old while the remaining respondents were 24 to 25 years old. To equally distribute the respondents between the control and experimental group, 23 of them received the reflection-oriented stimuli while the remaining 22 respondents did not receive the reflection-oriented stimuli.

Two sessions were conducted where 20 respondents participated in the first session and 25 respondents participated in the second session. The sessions were conducted in an enclosed studio within the premise of the university that originally serves as a studio room for the respondents. Respondents were informed that the aim of the experiment was to uncover their individual learning approaches. Hence, they should work on the design task individually and not engage in discussions or actions that could influence their design process.

5.3.2 Data collection: Questionnaire and graphical output

Data collected for this study comprised questionnaire items that were filled in by the respondents and graphical outputs that were produced when solving the given design problem. The respondents filled in a questionnaire at the beginning and at the end of the study. Items in the first questionnaire relate to variables on the *presage level* (see Appendix R). It assesses respondents' self-reporting regarding their design learning mind-set and preferred learning approaches. Prior to answering the questionnaire, respondents were asked to think of the design course that they had previously or are currently undertaking as a context for the questionnaire items. Respondents were asked to answer the questionnaire items as honestly as possible, according to how closely they relate to the scales as opposed to what they reckon as the "right" answer should be.

Items assessing design learning mind-sets were developed based on the two prior studies. The design learning mind-set of students was assessed on the discerning and the opportunistic mind-set scales. The discerning mind-set scale assesses students' interest in knowledge (3-items) and inclination for active experimentation (4-items), while the opportunistic mind-set scale assesses students' inclination to take convenient measures (5-items), administer routine actions (5-items). Another 5-items assess students' inclination for active or inactive reflection that measure the discerning or opportunistic mind-sets respectively. Scales for these items are reversed where necessary in the analyses. Examples of items in each scale are as follows:

1. Interest in knowledge:
- *I make an effort to understand new knowledge and concepts quickly.*
- *It is important to me that I come to class so that I can interact with my teachers directly.*

2. Active experimentation:

- *When in doubt, I will search for resources on my own.*
- *I continue to implement tasks my way even if it is done differently by others.*

3. Taking convenient measures:

- *I abandon design ideas if I realize that the final presented model cannot be constructed easily.*
- *I often depend on teachers to tell me what to do next.*

4. Administering routine actions:

- *I usually follow the teachers' instruction without questioning the reasons behind them.*
- *I often find inspiration on the internet, books, etc. while designing but I don't spend a lot of time researching these ideas thoroughly.*

5. Active or inactive reflection:

- *I usually examine closely the goal of the task that I am supposed to complete thoroughly before starting to design.*
- *Critique sessions help me see different ways of looking at things.*

The second questionnaire assessed respondents' perception of the design problem (see Appendix S). This questionnaire provides insights regarding how difficult the design problem was perceived and how satisfied respondents' were with the design solutions that they had produced. Respondents rated all questionnaire items on a Likert scale (1–5). Respondents were given an unlimited amount of A3 papers to work out their solutions. They were also requested to use a new piece of paper when they started to do something new in their process, according to their own perception. Such as when they start to sketch out solutions, subsequent to noting down aspects from the brief. Respondents were also asked to number the pages according to their sequence. The outputs produced ranged from a minimum of one to a maximum of seven sheets of A3 papers per respondent. The outputs that respondents produced consisted of combinations of images and textual notes.

The textual notes made by the respondents consists of the English and Malay language. These notes were kept in their original form as the people involved in evaluating or coding the data were fluent with both the English and Malay languages. An example of an output produced by Respondent 15 is shown in Figure 5.3). Respondent 15 worked out his solution on five pieces of A3 paper. The first three pages are related to considerations regarding the design problem. The last two pages are related to the solution that the respondent generated for the design problem. At

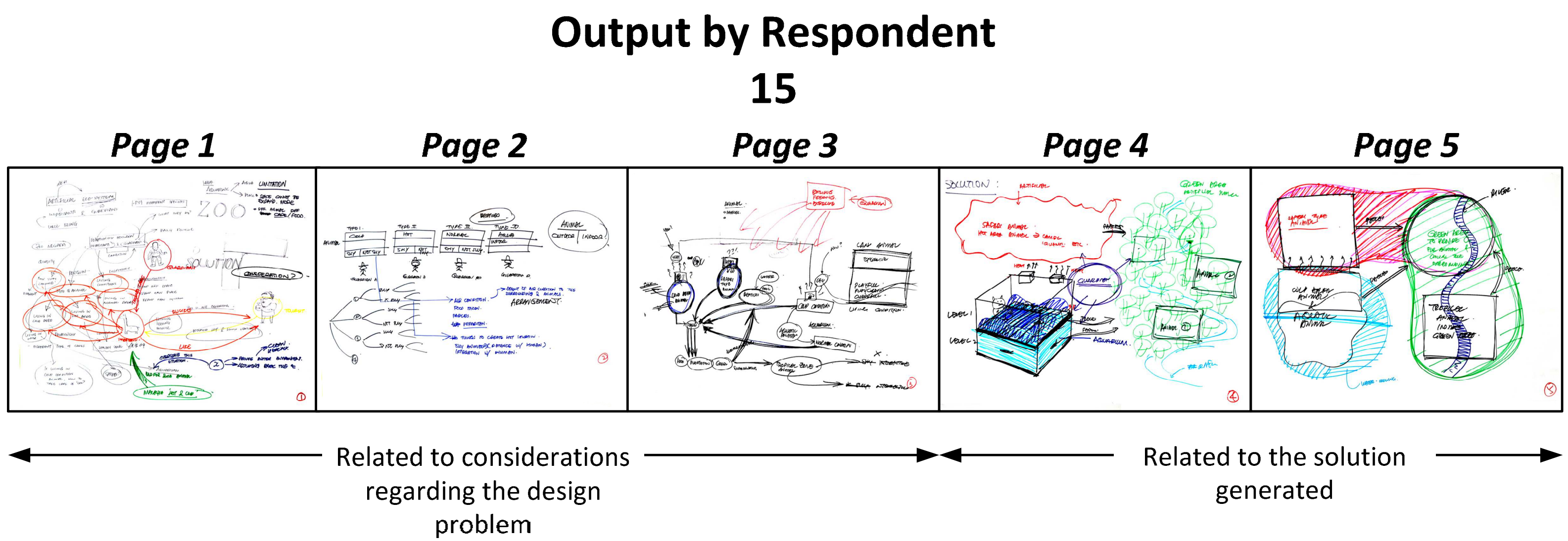

Figure 5.3 Example of output produced by Respondent 15 (5 pages of A3 paper)

the end of the experiment, every respondent produced one best final design solution. In the example of Respondent 15, his final design encompasses pages 4 and 5.

5.3.3 Design brief and stimuli

The design problem was conveyed through a design brief requiring a new design for the local national zoo that has remained unchanged since its initiation in 1963. This design problem introduces an element of ambiguity for the respondents as the design of the zoo requires them to contemplate large spatial areas on a macro-level. These students are trained as product designers and are more familiar with designing product and components on a micro-level. By introducing a complex and unfamiliar problem, it is expected that differences between the mind-sets will be more observable (see Section 5.1). A short description related to the zoo, its managing body and funding source was provided in the brief. Respondents were then requested to come up with a new design and suggest ways to enable their solutions to be realized i.e., implemented. Respondents in both the control and experimental groups received the same brief. Respondents in the experimental group received additional questions at the bottom of the design brief as their experimental treatment (see Appendix T), that acted as the reflection-oriented stimuli as discussed in section 5.1. Four questions were posed to respondents in the experimental group. Each of these questions are preceded by general facts related to the questions. This was done to vividly describe and avoid any forms of misunderstanding regarding the context of the questions (Graesser & Person, 1994). In the first question, the general fact that was stated prior to the question is:

Malaysia's tropical climate experiences hot and humid weather. Can you think of zoo animals that will have difficulties living in such climate?

The statement made prior to the question was meant to clarify the context of the question. In this case, it refers specifically to the local tropical climate which was hot and humid. The question next addresses the possible difficulties that the animals would face in such a climate. This formulation invites the respondent to diverge their thinking and take into consideration the needs of the various animals in the zoo. The formulation of the next three questions are as follows:

Zoo Negara is located near the city centre and has no possibilities of expanding. How will this affect the planning of habitat for animals that naturally live in large open areas e.g. savannah?

Most animals require different care-taking e.g. bathing, feeding, exercise. Some animals like interacting with humans while others don't. How will this affect the design of the zoo's utilities?

What other things can you take into consideration to help come up with a good design?

Respondents were asked to take the questions into consideration while designing. The questions were kept open-ended to elicit further consideration as opposed to short or close-ended "yes-no" answers (Charmaz, 2006b). The fourth and final question suggests that there could be other aspects that can be taken into consideration, apart from aspects posed by the previous questions. This question invites respondents to reflect more thoroughly of any other impending elements to consider during their design process. This approach was taken in order to induce reflection within the respondents in the experimental group.

5.3.4 Data analysis

Data collected for this study are analysed using both qualitative and quantitative analysis methods. The questionnaire data is analysed quantitatively. The outputs produced by the respondents are qualitatively analysed, prior to the quantitative analyses. The procedure taken to analyse the outputs is illustrated in Figure 5.4.

As previously indicated, the total number of pages produced by Respondent 15 is five pages. The first three pages are categorised as the respondents' considerations and the remaining two pages as his solution. In reality, the number of pages produced by the respondents differ individually, ranging from a minimum of one to a maximum of seven pages. Depending on the amount of pages generated by respondents, the total number of pages that they individually produced, were used in this analysis. The process of categorising were subjectively done by the author to the best of her judgement. However, as explained in Section 5.3.2, respondents were asked to use a new piece of paper when they decided to start something new in their design process. This additional information on the respondents' own judgement of the "jumps" in their own design process supported and substantiated the conducted categorisation.

The outputs are divided into two parts and categorised either as the respondents' *considerations* or *solution.* This was to done to differentiate between the two types of data. Respondents' considerations are extracted and visualised into their *considerations network (CN).* The *CN* displays the inter-relations of considerations that were made by the respondent. Additionally, respondents' solutions are digitalised and original texts written by the respondents in their solutions were re-typed. These solutions were next evaluated by two designers. Both designers are trained as industrial designers and have a minimum of eight years of experience practicing designing after their bachelor education. They scored the solutions on the five scales that assess creativity (see Section 5.2.3).

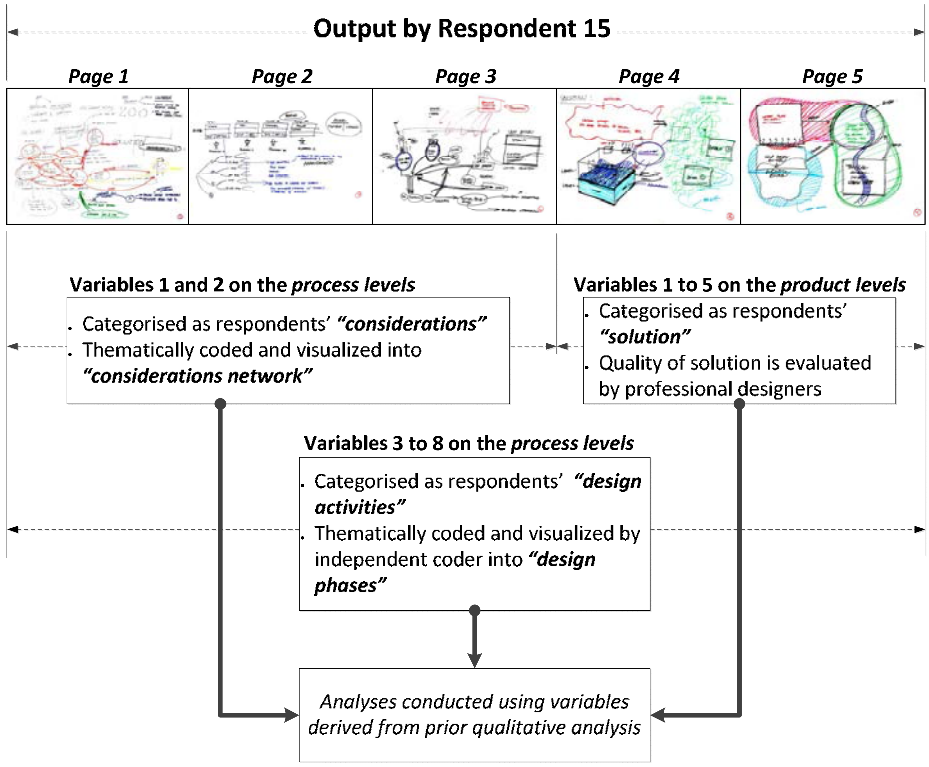

Figure 5.4 Phases of analysis for the outputs

The outputs are also used to identify the different design activities conducted by the respondents. These data were thematically coded and visualized into their *design phases (DP)*. Variables extracted from the *DP* (respondents' overall design process), *CN* (considerations prior to proposal of solution) and the quality of solutions were next quantitatively analysed. Details of the *DP*, *CN* and the method of analysis for the three different categories of data are described in the following sections.

5.3.5 Coding the Design Phases (DP)

Respondents' outputs were thematically coded with regards to their design activities. Parts of respondents' outputs were classified into discrete categories that describe their distinct design activities (Cohen et al., 2007). The design activities were next represented in visual diagrams, depicting the respondents' design processes. This visual diagram is referred to as their *design phases* (DP). This analysis was done by an independent rater pursuing her Master's degree at TU Delft. The independent rater is fluent in both the Malay and English language, and has prior knowledge of qualitative coding methods. The design activities that the respondents conducted were first coded thematically using an inductive coding method (Miles et al., 1994; Saldana, 2009). This means that the codes developed progressively during the analysis.

From this process, 35 codes were generated describing the design activities respondents engaged in. However, after a review of the codes by the author, some codes were found to overlap with each other. For example, the code "explore solution" and "explore ideas" was used for two separate occurrences that were similar to one another. The difference between an idea and solution were too subtle, as an idea could also be considered as a solution. Subsequently, a discussion was held between the author and the independent rater to review the existing codes. The outcome of the discussion resulted in the subsuming of similar design activities. In this case e.g. all occurrences coded as "exploring ideas" were subsequently coded as "exploring solutions". Several other codes were also merged and renamed, while others were retained in their original form. This method connotes actions well and was thus used for this purpose (Miles et al., 1994; Saldana, 2009). The final codebook of design activities consists five main codes that capture the activities conducted by the respondents in the form of gerunds ("-ing" words) (see Table 5.2).

The five main codes include activities such as *exploring, identifying, proposing, reflecting* and *detailing out*. These design activities are very well-aligned with the existing phases of the design process (Howard et al., 2008; Lawson, 2006). Several sub-codes were generated for each of these activities. The sub-codes generated for *exploring* consists of eight aspects that the respondents explored. This includes: *topics, objectives, problems, solutions, approaches, insights, needs* and *implementation*. A design activity that was conducted by the respondents were coded using a combination of the main code and a sub-code. For example, the activities that respondents conducted would be coded as "exploring topics" or "exploring approaches" etc. The other main codes had five (*identifying*), two (*proposing*), two (*reflecting*) and two (*detailing out*) sub-codes respectively. As an example, the activity *exploring approaches* refers to "examining the ways or means of possibilities on how to proceed with the given problem". See an extract of a respondent's output that was coded as *exploring approaches* in Figure 5.5. The respondent began by questioning the method or way to improve the problem and the aspects to be taken into consideration. She next distinguished two aspects to be focussed upon (inhabitants and guardians) for the artificial ecosystem. The whole input-output like diagram generated by Respondent 2 is coded as *exploring approaches.*

Table 5.2 Codes and sub-codes of design activities

Code	No.	Sub-codes	Description
Exploring	1	Topic(s)	Exploration of specialised topics that are related to the design problem.
	2	Objective(s)	Exploration of goals of the project or other outcome based intentions that the student aims to achieve.
	3	Problem(s)	Exploration related to the design problem i.e...breaking down aspects of design problem.
	4	Solution(s)	Exploration of solution ideas.
	5	Approach(es)	Exploration of possibilities on how to proceed on the project.
	6	Insight(s)	Exploring aspects that were gained from own considerations that were made on the design problem.
	7	Need(s)	Exploring the requirements of stakeholders involved in the design problem.
	8	Implementation	Exploring on how to realize the solution i.e. how to make their solution work.
Identifying (differs from explore. When identifying. students already start pin-pointing critical aspects)	1	Problem(s)	Determining aspects of the problem.
	2	Connection(s)	Distinguishing relations between aspects involved in the design problem.
	3	Insight(s)	Makes critical aspects of observations explicit.
	4	Objective(s)	Determines goals or intentions to achieve.
	5	Approach(es)	Determines method, ways or steps to proceed with in the design task.
Proposing	1	Solution	Proposes solution to solve the design problem.
	2	Concept	Proposes an idea that is not yet finalized as the proposed solution.
Reflecting	1	Solution	Reflecting on the solution that has been proposed.
	2	Need	Reflecting on the need of the stakeholders.
Detailing out	1	Solution	Expands upon aspects of the solution.
	2	Benefits	Details out benefits that can be obtained by implementing the solution proposed.

The design activities that were coded are next represented in the form of visual diagrams by the independent coder (see Figure 5.6). This was done to achieve uniformity across the disparate data of the original outputs (Cohen et al., 2007). The condensation of respondents' design activities into these visual diagrams facilitates meaningful comparisons to be made. The coding and diagrams generated by the independent coder were cross-checked by the author and any irregularities between the actual data and coded diagrams were reviewed and re-iterated. These diagrams are referred to as the *design phases (DP)* of respondents. Figure 5.6 illustrates the *DP* of Respondents 2 and 28. The *DP* of Respondent 28 on the right consists of two activities: *exploring problem* and *proposing solution.* Respondent 2 on the left engaged in six design phases, beginning with *exploring approach* to *proposing solution.*

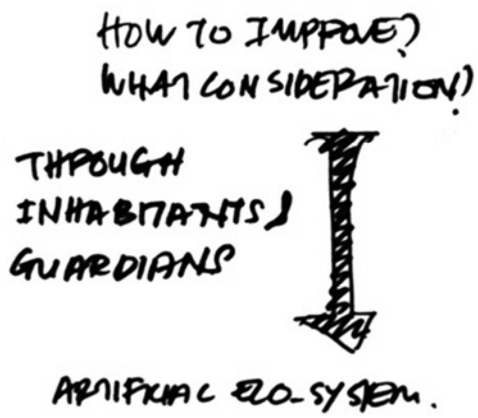

Figure 5.5 Extract from Respondent 2 which was coded as "exploring approaches"

From the *DP,* four variables on the process level are extracted (see variables numbered 3 to 6 in the conceptual framework of Figure 5.1). The first variable is related to the number of specialised topics that respondents considered (Variable 3 in conceptual framework). This is represented by the dark grey boxes in Figure 5.6. Respondent 2 has considered five different topics (environment, guardian, maintenance, human and animal) while Respondent 28 did not consider any specific topics within the problem given. The range of specialised topics that respondents considered ranged between zero and six topics (M=2.35, SD=1.72).

The black dots represent a subjective evaluation of the comprehensiveness of each design activity (see Figure 5.6). The black dots refer to a subjective assessment of the collective depth, expanse and connections that the respondent made in each design activity. They are placed to the left of each design activity. The level of comprehensiveness of design activities ranges from a minimum of one dot (●=low comprehensiveness) to a maximum of four dots (●●●●=high comprehensiveness).

Respondent 28 was evaluated as engaging in low level of comprehensiveness (●) on the design activities of *exploring problem* and *proposing solution.* Respondent 2 engaged in medium-low (●●) to high (●●●●) levels of comprehensiveness in her design activities.

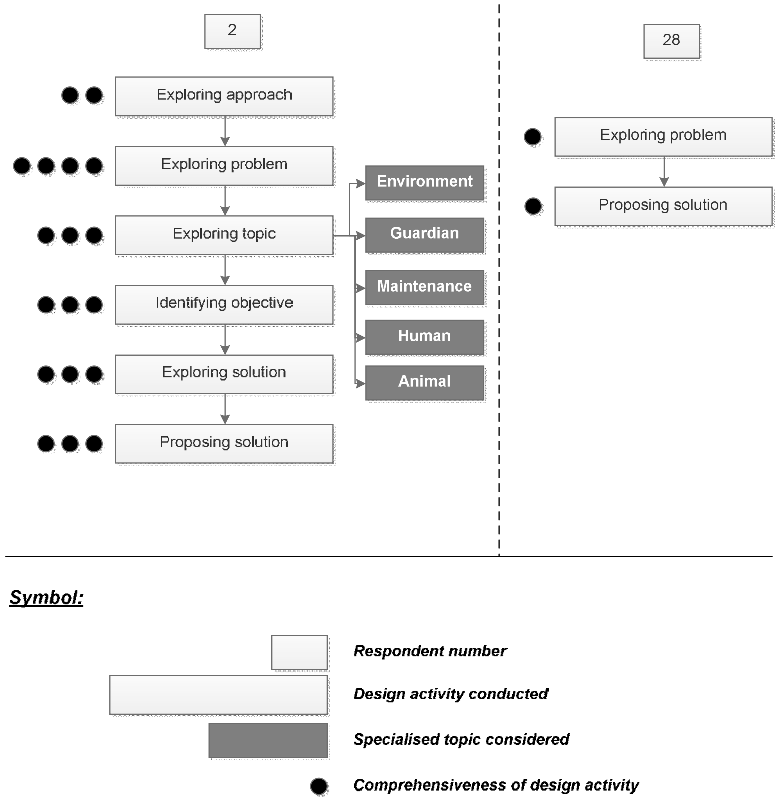

Figure 5.6 Example of diagrams illustrating the "design phases" of Respondents 2 and 28.

The second variable is related to the comprehensiveness of specialised topics considered (Variable 4 in the conceptual framework). By referring to the black dots of the design activity *exploring topics*, Respondent 2 engaged in this activity on a medium-high level (●●●). Similar to the assessment of the comprehensiveness of design activities, the level of comprehensiveness that respondents engaged in the specialised topics is assessed as a minimum of one dot (●=low comprehensiveness) to a maximum of four dots (●●●●=high comprehensiveness) (M=2.16, SD=1.38). The third variable is related to the number of phases in a respondents' design process (Variable 5 in the conceptual framework). Respondent 2 engaged in six different design activities, representing six different phases in her design process. Respondent 28 engaged in two design phases. The number of phases respondents engaged in range from one to six phases (*M*=3.18, *SD*=1.28). The fourth variable is related to the comprehensiveness of design activities that respondents engaged in (variable 6 in conceptual framework). Equally, it refers to the sum of comprehensiveness for all design activities an individual engages in, or the aggregation of all the black dots in each respondents' *DP*. As illustrated in Figure 5.6, Respondent 2 has a score of 18 dots while Respondent 28 has a score of 2 dots for comprehensiveness of design activities. In this sample of respondents, the score of comprehensiveness ranges between 1 and 22 (*M*=8.11, *SD*=4.57, *Median*=7.00, *Mode*=4.00 and 8.00).

5.3.6 Coding the Consideration networks (CN)

All items that were considered by the individual respondents, prior to the solution they propose, are mapped into a visual network. This visual network is referred to as the respondents' *consideration network* (*CN*). The consideration networks generated range from simple (see Figure 5.7 top) to more complex (see Figure 5.7 bottom) networks.

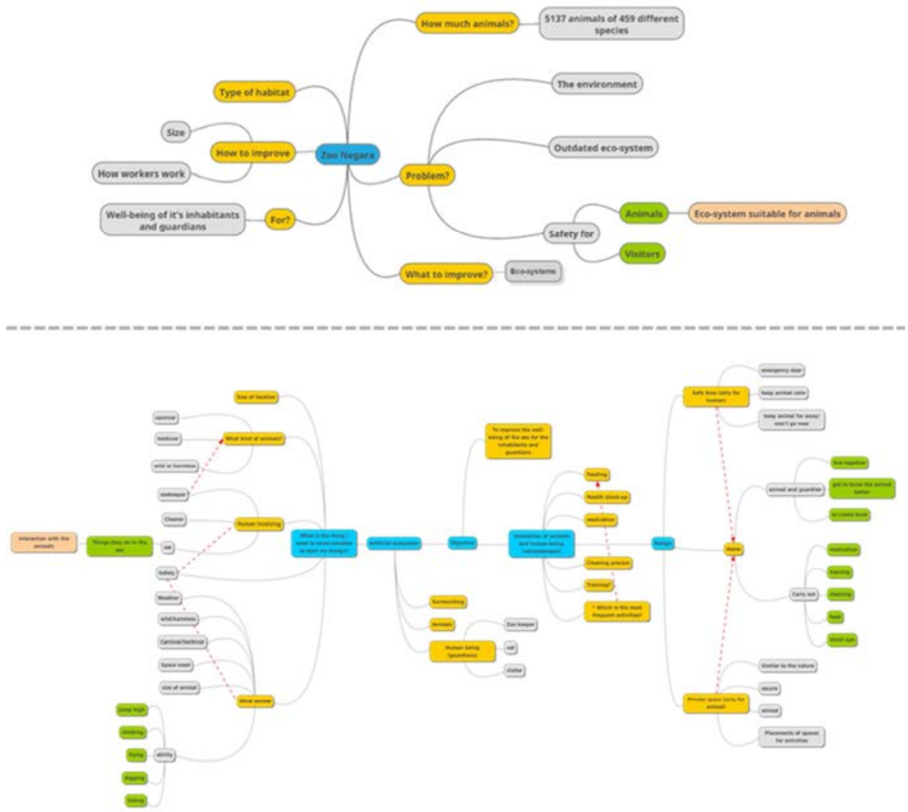

Figure 5.7 Example of "consideration networks" for Respondent 30 (top) and Respondent 1 (bottom)

Each box in the *CN* represents an item that was considered by the respondent. Grey lines are used to connect considerations that are taken into account by the respondent. The red dotted lines are used to represent explicit connections that the respondents made themselves. The boxes in the *CN* are colour coded to differentiate the different levels of considerations that were made.

From the *CN,* two variables on the process level are extracted (see variables numbered 1 and 2 in the conceptual framework of Figure 5.1). The first variable is related to the total number of considerations that the respondent considered (see Variable 1 in conceptual framework) i.e., the total number of boxes in each *CN.* The total number of considerations within this sample of respondents range between five and 87 (M=35.14, SD=19.05). As an example, Respondent 30 has a total of 18 considerations and Respondent 1 has 62 (see Figure 5.7).

The next variable extracted from the *CN* is the number of considerations that respondents commenced with in the *beginning*. This refers to the blue boxes in the *CN.* In the top example, Respondent 30 starts with one item (blue box) and subsequently considered six other aspects (yellow boxes). In the bottom example, the Respondent 1 starts with five considerations (blue boxes) and breaks each of it down (represented by the yellow boxes). Respondent 30 has one consideration in the beginning while Respondent 1 has five. These considerations are subsequently followed by the various differing coloured boxes. Respondents in this sample considered a minimum of one to a maximum of 11 aspects in the beginning of their design process (M=4.91, SD=2.68).

5.3.7 Coding the Design spaces: Problem and solution spaces

The design activities that respondents engaged in are visualised in the form of diagrams as their *DP.* For the coding of their design spaces, the design activities that respondents were engaged in were subsequently categorised as either problem-related or solution-related. This is because respondents engaged with either the problem or solution throughout the duration of solving the design problem. Design activities such as exploring specialised topics related to the design problem and identifying objectives to be achieved in the design task are related to the problem. Thus it was categorised as a problem-related design activity.

Design activities such as exploring ideas and solutions were related to the solution. Hence it was categorised as a solution-related activity. Some respondents allocated more time toward exploring the problem, while others allocated more time exploring the solution. However, there are also respondents who balanced their attention between the problem and solution. These respondents would have about the same amount of design activities allocated to the problem and to the solution (see Figure

5.8). The number of specific design spaces that each respondent engaged in were tallied. These values are used as Variables 7 and 8 in the *process level*. With reference to Figure 5.6, Respondent 1 engaged in three problem-related design activities (*exploring approaches, exploring topics and identifying objectives*) and two solution-related design activities (*exploring solution and proposing solution*).

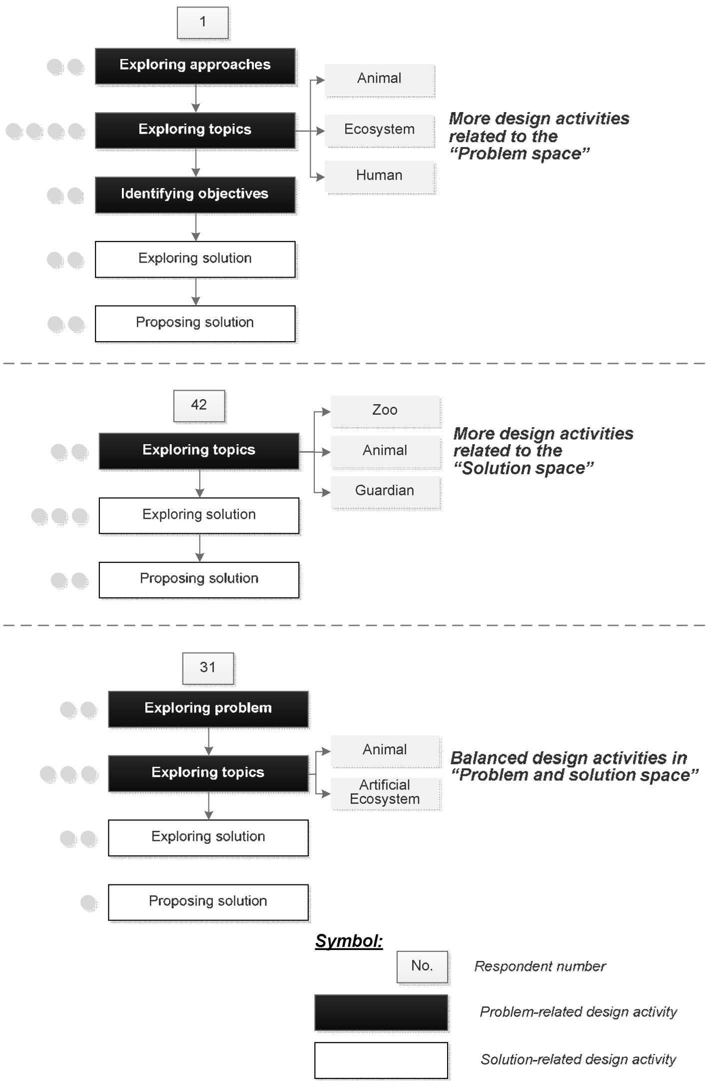

Figure 5.8 Categorising problem-related and solution-related design activities: How to calculate the number of problem and solution related design activities. Examples from Respondents 1, 42 and 31.

Respondent 42, engaged in two solution-related design activities (*exploring solution and proposing solution*) compared to one problem-related design activity (*exploring topics*). Finally, Respondent 31 engaged in two design activities for both the problem (*exploring problem and exploring topics*) and solution (*exploring solution and proposing solution*) related design activities. In this sample of respondents, they engaged in a minimum of 0 to a maximum of 4 problem-related design activities (*M*=1.42, *SD*=0.99, *Median*=1.00, *Mode*=1.00) and a minimum of 1 to a maximum of 4 solution-related design activities (*M*=1.76, *SD*=0.83, *Median*=2.00, *Mode*=1).

5.3.8 Evaluating the Quality of solutions

The quality of solutions produced by respondents was evaluated by two experienced product designers. Both designers are trained as industrial designers and have a minimum of eight years of experience practicing designing after their bachelor education. These evaluations are treated as variables within the *product level* for the subsequent quantitative analysis. The evaluators assessed the solutions on five different categories of quality as discussed in Section 5.2.3. This includes the *clarity*, *completeness*, *usefulness*, *feasibility* and *originality* of the solutions. These categories of quality were scored on a minimum of one to a maximum of five. Additionally, the aggregated mean of the five scales is computed as the mean quality score for all respondents.

The evaluators were given digital files containing three items: (1) the design brief respondents received; (2) the scales for assessing the quality and originality of solutions (see Appendix U); and (3) the solutions of all 45 respondents. The evaluators were briefed about the design brief, scales for assessment and solutions. Next, they were asked to evaluate the solutions on their own. The evaluators were not informed of the research study or background information related to the respondents. Thus, they were assessing the solutions purely based on the scales. The evaluators were thus not compelled to evaluate the solutions differently based on any background differences between the respondents i.e., their mind-sets, educational background, gender, etc. The evaluation of the solutions was purely based on the extent to which the solution provides for the problem of redesigning the local zoo.

The Spearman's correlational analysis is used to examine the inter-rater reliability between the two evaluators. The correlation between the individual sub-scales of quality as scored by the two evaluators is reported using the correlation coefficient, *r*. Values of ±.30 and ±.5 represents a medium and large agreement effect between the two raters, respectively (Field, 2013). Three scales were significantly positive with medium agreement effects in this analysis. Firstly, on the scale of *clarity*, r=0.38, n=45, p=.011. Secondly on the scale of *usefulness* r=0.46, n=45, p=.001 and thirdly on the scale of *feasibility* r=0.30, n=45, p=.043. This means that the two evaluators rated the *clarity*, *usefulness* and *feasibility* of solutions produced by the respondents in positively moderate agreement. Two scales were significantly positive with strong agreement effects. This includes the scale of *completeness,* r=0.39, n=45, p=0.008 and *originality,* r=.55, n=45, p=.000. Both of the scales were highly significant with p-levels of <0.01.

5.3.9 Evaluating the Clarity of solutions

The *clarity* of solutions is evaluated on a scale of one *(not clear at all)* to five *(very clear)*. Solutions that can be understood more easily would have higher scores in terms of clarity. Solutions that are scored as five in this scale would be solutions that can be understood easily. For example, Respondent 3 received a score of four out of five from each evaluator (see Figure 5.9).

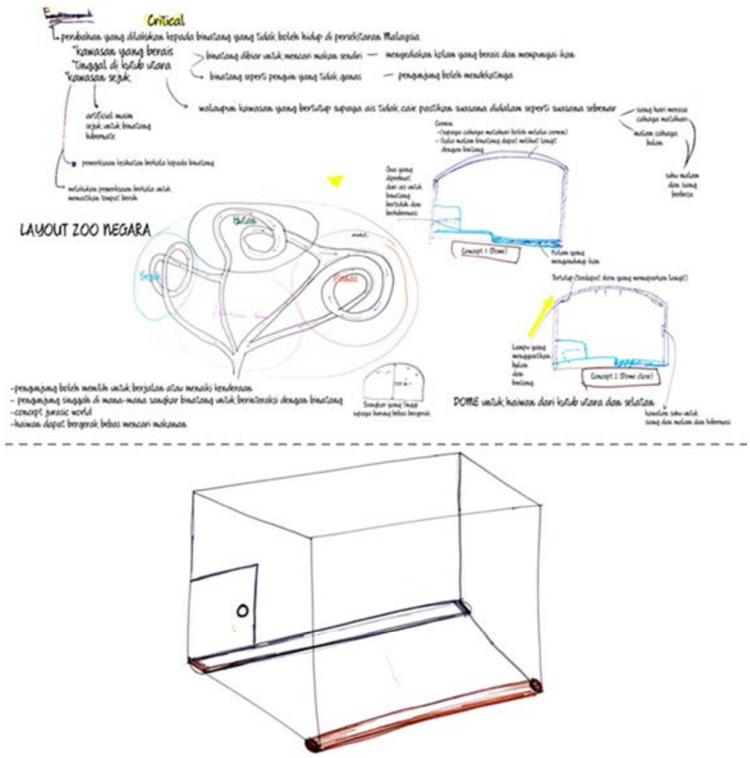

Figure 5.9 Solutions by Respondent 3 (top) and Respondent 20 (bottom)

The solution provided by this Respondent 3 is assessed as coherent but requires effort to be understood. This is possibly due to the considerable amount of information i.e., description provided. However, the descriptions provide clarity regarding the ideas behind the solutions. Thus the degree to which the solution was communicated was assessed as rather high, although the solution was not immediately deciphered. Solutions that are rated 1 on this clarity scale can be described as solutions that are completely ambiguous and incoherent. This means that respondents were not able to articulate their solution well and that the evaluators would have difficulty to understand the idea behind the solution that they proposed. For example, Respondent 20 (see Figure 5.9) received a score of one out of five from each evaluator.

5.3.10 Evaluating the Completeness and Usefulness of solutions

The *completeness* of solutions are evaluated on a scale of one *(not complete at all)* to five *(very complete)*. A solution that is scored highly on this scale is more likely to solve the problem compared to a solution that scored low. For example, Respondent 15 received a score of four out of five by both evaluators on this completeness scale. In contrast, Respondent 19 received a score of one and two by the respective evaluators (see Figure 5.10).

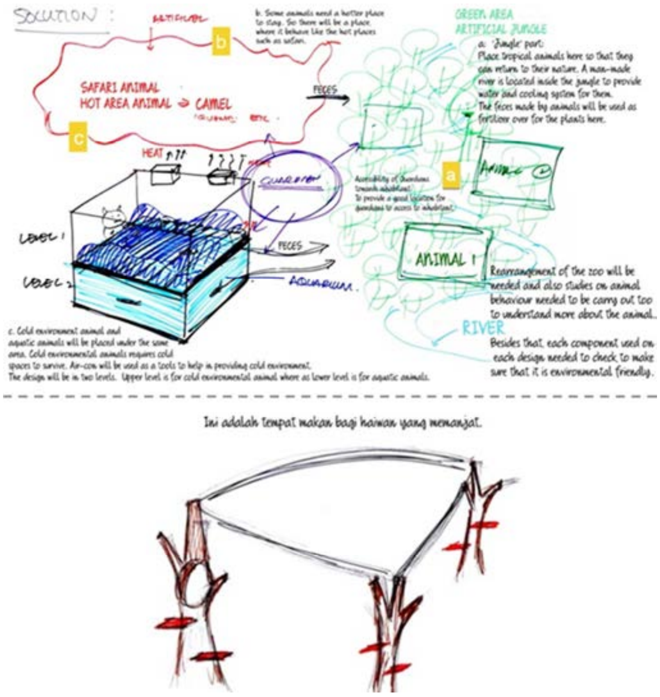

Figure 5.10 Solutions by Respondent 15 (top) and Respondent 19 (bottom)

The brief required that respondents redesign the zoo for the well-being of the animals and the guardians of the zoo. The solution proposed by Respondent 15 is rated as a reasonable solution that would contribute to a big part of fulfilling this requirement i.e., solving this problem. The solution solves a systems aspect of the zoo that involves most, if not all, of the animals living in the zoo. In comparison the solution proposed by Respondent 19 solves certain conditions for one animal in particular. This solution is rated as being unlikely (score of two) and as not solving (score of one) the given problem of redesigning the zoo. In other words, the solution has a low level of completeness.

The *usefulness* of solutions is evaluated on a scale of one *(not useful at all)* to five *(very useful).* The cumulative mean scores of both evaluators for this scale is M=3.34, SD=0.80. Solutions that pose considerable benefits to the stakeholders involved are more likely to be scored highly on this scale. In comparison, solutions that are scored low on this scale are deemed to pose considerable disadvantages to the stakeholders involved. Respondent 15 received a score of five and four from the two evaluators. Respondent 19 however received a score of one and two respectively. This means that the solution proposed by Respondent 15 is deemed to pose slight to considerable benefits to the stakeholders involved. In comparison, the solution proposed by Respondent 19 is considered to pose slight to considerable disadvantages to the stakeholders involved.

5.3.11 Evaluating the Feasibility and Originality of solutions

The *feasibility* of solutions is evaluated on a scale of one *(not feasible at all)* to five *(very feasible).* The more easily a solution can be produced or implemented (in terms of manufacturing capabilities, availability of technology and changes from the existing technology), the more likely that a solution receives a high score on this scale. In contrast, the more difficult it is to implement the solution, the more likely the solution is scored low on this scale (see Figure 5.11).

The solution produced by Respondent 14 is an example of a solution that receives a score of four out of five by both evaluators. In contrast, the solution produced by Respondent 8 was scored as two out of five. The solution proposed by Respondent 14 requires minimal to moderate amount of alterations to the existing system that is adopted in the current zoo. On the other hand, the solution as proposed by Respondent 8 requires an absolute alteration of the existing architecture throughout the entire zoo. This increases the level of difficulty to implement the solution.

The *originality* of solutions is evaluated on a scale of one *(not original at all)* to five *(very original).* A highly original solution (score of five) is unexpected, imaginative and surprising i.e., questions the problem definition entirely. In contrast, when the proposed solution already exists within the pool of 45 solutions i.e., is commonly proposed by the other respondents, it is considered as mundane or boring, and it's

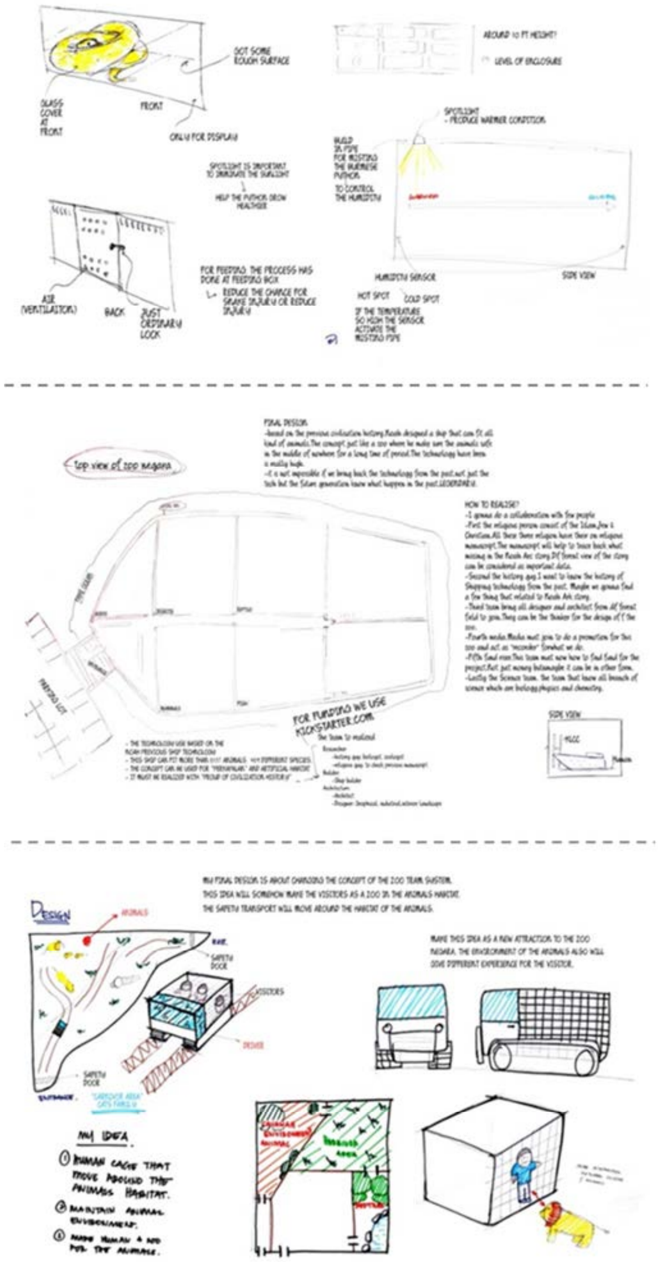

Figure 5.11 Solutions by Respondent 14 (top) and Respondent 8 (middle) Respondent 17 (bottom)

score on originality decreases. The solution produced by Respondent 8 was rated as four out of five by both evaluators. This solution suggests distinct thematic architectural features to be implemented in the redesign of the zoo. This approach is not suggested by any of the other 44 respondents. The solution is thus considered as unusual and showing some imagination. In contrast the solution produced by Respondent 17 was scored as one and two out of five by the respective evaluators. This solution encapsulates a means of transportation within the zoo that is commonly suggested by other respondents too. More specifically, six other respondents had in a way or other, embedded similar elements into their solutions. The two evaluators considered this solution as common and mundane, differing only slightly from existing solutions (see also Figure 5.11).

5.3.12 Reliability of questionnaire scales

In the first questionnaire, the design learning mind-sets and the preferred learning approaches of respondents are assessed. Design learning mind-sets are assessed on two different scales: the discerning and opportunistic mind-set scale. Preferred learning approaches are measured on three scales: deep, strategic and surface learning approaches. Items on each of the scales are analysed for their consistency to reflect the construct of mind-sets and preferred learning approaches that is assessed (Field, 2013). Reliability analysis using Cronbach's alpha is used for this purpose (see Appendix V).

12 items were originally used to measure the discerning mind-set variable and 15 items were used to measure the opportunistic mind-set variable. The reliability analysis shows high reliabilities of Cronbach's α=0.76 and 0.71 for the discerning and opportunistic mind-set scales respectively. The high reliabilities are acquired after five items were removed from the discerning mind-set scale and two items from the opportunistic mind-set scale. Deletion of the items was done to improve the reliability of the scales (Field, 2013).

Examples of the items retained to assess a respondent's inclination towards a discerning mind-set are as follows: (1) I make an effort to understand new knowledge and concepts quickly; (2) When in doubt, I will search for resources on my own; and (3) I try to associate information I receive with my design ideas in order to develop it further. High agreement to these items reflects a mental inclination to seek understanding and behavioural tendencies that relate to actively reflecting and experimenting in design learning.

Examples of the items retained to assess a respondent's inclination towards an opportunistic mind-set are as follows: (1) I abandon design ideas if I realise that the final presented model cannot be constructed easily; (2) I usually follow the teachers' instruction without questioning the reasons behind them; and (3) I usually try to explore aspects of a project that are not mentioned by the teacher. The third item is reversely phrased, thus calculated as a reverse item (Cohen et al., 2007; Field, 2013). High agreement to these items reflects a mental inclination to seize opportunities presented and are related to behavioural tendencies that relate to taking convenient measures and administering routine actions.

Six items were originally used to measure the deep learning approach. The reliability analysis shows that the Cronbach's $\alpha=0.69$ for this scale. A value of 0.70 to 0.80 is commonly regarded as an acceptable value for the Cronbach's α. Examples of items retained to assesses a respondent's preference for a deep learning approach are as follows: (1) I try to relate ideas I come across to those in other topics or other courses whenever possible; (2) When I read, I examine the details carefully to see how they fit together; and (3) It's important for me to be able to follow the argument, or to see the reason behind things. High agreement to these items indicate a preference to relate ideas and use evidence in learning.

The strategic learning approach scale originally consists of 12 items. After removing four items from this scale, a high reliability of Cronbach's $\alpha=0.78$ is found. Examples of the items retained to assesses a respondent's preference for a strategic learning approach are as follows: (1) I organise my study time carefully to make the best use of it; (2) I'm quite systematic and organised when it comes to revising for exams; and (3) When I finish a piece of work, I check it through to see if it really meets the requirements. High agreement to these items indicate a preference to manage study time, organise study activities, and monitor one's own effectiveness in learning.

Finally, the surface learning approach scale was originally measured using nine items. A reliability of Cronbach's $\alpha=0.72$ was found for this scale after removing three items. Examples of the items retained to assess a respondent's preference for a surface learning approach are as follows: (1) I like to be told precisely what to do in essays or other assignments; (2) I concentrate on learning just those bits of information I have to know to pass; and (3) I'm not really interested in this course, but I have to take it for other reasons. High agreement to these items indicate a lack of purpose in taking a course. It also indicates a tendency to be bounded by the syllabus and inclination towards memorise unrelated information.

5.3.13 Categorising the respondents into either discerning or opportunistic mind-set groups (using the questionnaire items)

In general, respondents scored themselves more highly on the discerning as compared to the opportunistic mind-set scale. This can be observed from the mean, median and range of scores for the two scales (see Table 5.3).

Table 5.3 Descriptive values for the opportunistic and discerning scales.

	Discerning Scores	Opportunistic Scores
Mean	3.70	2.68
SD	0.52	0.40
Median	3.86	2.62
Min	2.29	1.77
Max	4.71	3.46

On the discerning mind-set scale (*M*=3.70, *SD*=0.52, *Median*=3.86) the scores range from a minimum of 2.29 to a maximum of 4.71. On the opportunistic mind-set scale (*M*=2.68, *SD*=0.40, *Median*=2.62), the scores range from a minimum of 1.77 to a maximum of 3.46. A hierarchical cluster analysis is next used to find similarities between respondents on their self-ratings for the discerning and opportunistic scales. The *Between-groups linkage* cluster method was used with a *Squared Euclidean distance* interval measure. Three clusters emerged from this analysis (see Table 5.4). The three clusters consisted of 19, 21 and five respondents respectively.

Table 5.4 Descriptive values for the three clusters that emerged from the hierarchical cluster analysis and the final two clusters used for subsequent analyses

	Cluster 1: High opportunistic, low discerning (N=19)		Cluster 2: High discerning, High opportunistic (N=5)		Cluster 3: High discerning, low opportunistic (N=21)		Cluster 1 & 2 High opportunistic (N=24)	
	Discerning Scale	Opportunistic Scale	Discerning Scale	Opportunistic Scale	Discerning Scale	Opportunistic Scale	Discerning Scale	Opportunistic Scale
Mean	3.22	2.96	4.10	2.35	3.86	3.00	3.35	2.97
Maximum	3.57	3.46	4.71	2.62	4.00	3.38	4.00	3.46
Median	3.43	2.85	4.00	2.46	3.86	2.92	3.43	2.92
Minimum	2.29	2.46	3.71	1.77	3.71	2.69	2.29	2.46
Standard Deviation	.36	.29	.27	.23	.10	.26	.42	.28

A review of the mean, median, maximum and minimum values reveal that respondents in Cluster 3 are strikingly different from Clusters 1 and 2. The maximum score on the discerning scale for Cluster 2 is fairly higher compared to Clusters 1 and 2. Additionally, the minimum score on the opportunistic scale within Cluster 3 is fairly lower compared to Clusters 1 and 3. On the other hand, in Clusters 1 and 2, the mean, median, maximum and minimum values for the opportunistic scale are fairly comparable. Furthermore, although the values of the discerning scale in Cluster 1 is lower compared to that of Cluster 2, the values in both Clusters 1 and 2 are lower compared to Cluster 3. Clusters 1 and 2 are re-categorised as one high opportunistic-low discerning and cluster. Additionally, Cluster 3 is categorised as a high discerning-low opportunistic cluster. 21 respondents fall into the high discerning-low opportunistic cluster and 24 respondents fall into the high-opportunistic-low discerning cluster.

An independent T-test is next used to validate the differences between the discerning and opportunistic mind-set clusters. This analysis validates the differences between the high discerning and high opportunistic mind-set clusters on the two scales. Firstly, respondents in the high discerning mind-set cluster (M=4.10, SD=0.27) have significantly higher scores on the discerning mind-set scales compared to respondents in the high opportunistic mind-set cluster (M=3.35, SD=0.42); $t(43)$=-6.95. p=.000. A strong effect size can be reported for this differences with Cohen's d=2.11. Secondly, respondents in the high opportunistic mind-set cluster (M=2.897, SD=0.28) have significantly higher scores on the opportunistic mind-set scales compared to respondents in the high discerning mind-set group (M=2.35, SD=0.23); $t(43)$=48.11. p=.000. A strong effect size can also be reported for this difference with Cohen's d=2.42. The strong effect sizes for both clusters indicate the large differences between the two clusters in terms of respondents' inclination toward a discerning or opportunistic mind-set. These differences are related to the mental inclinations and behavioural tendencies that respondents adopt. Respondents in the high discerning cluster=seek understanding, and actively reflect and experiment in their design learning. Respondents in the high opportunistic cluster however, incline toward taking convenient measures and administering routine actions in their design learning.

5.4 Results

In this section, the results of analyses that tests the inter-connections between presage, process and product level variables are discussed.

5.4.1 The different learning approaches that discerning and opportunistic mind-sets prefer (RQ 1)

RQ 1: "*Do opportunistic and discerning mind-set students prefer to approach their learning differently?*" is addressed in this section. The Spearman's correlation analysis is used to examine the relationship between the mind-sets of the respondents and the learning approach that they prefer (see Table 5.5). From this analysis, large positive correlations can be found for the deep, r=.53, n=45, p=.000 and strategic, r=.51, n=45, p=.000 learning approach scores with the discerning mind-set scores. No correlations can be found between the surface learning approach scores to the discerning mind-set scores. This means that when respondents rated themselves highly on the discerning mind-set items, they would also rate themselves highly on the deep and strategic learning approach items.

The opportunistic mind-set scores are strongly and negatively correlated to the deep learning approach scores, r=-.57, n=45, p=.000. It is also positively correlated with medium strength to the surface learning approach scores to r=.47, n=45, p=.001. No correlations can be found for the strategic learning approach scores to the opportunistic mind-set scores. This means that as respondents' rating on the opportunistic mind-set items increased, their self-ratings on the surface learning approach items also increased, while their self-ratings on the deep learning approach items decreased.

Table 5.5 Spearman's correlations between mind-sets and learning approaches scores

	1	2	3	4
1. Discerning mind-set	—			
2. Opportunistic mind-set	-.71**	—		
3. Deep learning approach	.53 **	-.57 **	—	
4. Strategic learning approach	.51**	-.22	.07	—
5. Surface learning approach	-.13	.47**	-.08	.08

**Correlation is significant at p< 0.01 (2-tailed).

An Independent T-test is next used to validate these results. The preferred learning approaches of the discerning and opportunistic mind-set groups are compared in this analysis. This analysis reveals significant differences between the two mind-sets on two preferred learning approach scales (see Table 5.6).

Table 5.6 Comparison between discerning and opportunistic mind-set types: Preferred learning approaches

Scale	High Discerning mind-set N=21 Mean (SD)	High Opportunistic mind-set N=24 Mean (SD)	Effect size. Cohen's *d*
Deep learning approach **	4.09 (0.38)	3.57 (0.51)	1.16
Surface learning approach	2.85 (0.95)	3.05 (0.60)	0.25
Strategic learning approach *	3.58 (0.55)	3.12 (0.58)	0.81

*T-test on average scores over two clusters was significant at p<0.05.
**T-test on average scores over two clusters was significant at p<0.01.

Respondents clustered in the discerning mind-set group (*M*=4.09, *SD*=0.38) rated a higher preference for the deep learning approach compared to respondents clustered in the opportunistic mind-set group (*M*=3.57, *SD*=0.51), *t*(43)=-3.47, *p*=.001. Additionally, respondents in the discerning mind-set group (*M*=3.58, *SD*=0.55) rated a higher preference for the strategic learning approach compared to respondents in the opportunistic mind-set group (*M*=3.12, *SD*=0.58), *t*(43)=-3.47, *p*=.014. Both the deep and strategic learning approach scales showed large sample effect sizes of Cohen's *d*=1.16 and 0.81 respectively. These large values indicate large differences between respondents in the discerning and opportunistic mind-set groups with respect to their preference in terms of deep and strategic learning approaches.

Scores on the surface learning approach scale were not significantly different between respondents in the opportunistic mind-set group (*M*=3.05, *SD*=0.60) compared to respondents in the discerning mind-set group (*M*=2.85, *SD*=0.95), *t*(0.76)=19.80, *p*=.454. Furthermore, the surface learning approach scale has a small effect size of Cohen's *d*=0.25. This means that respondents' preference for surface learning approach were not different between the discerning and opportunistic mind-set groups. To conclude RQ1, discerning and opportunistic mind-sets students prefer to approach their learning differently. Students that incline toward the discerning mind-set indicated higher preference for deep and strategic learning approaches. In contrast, students that incline toward the opportunistic mind-set indicated lower preference for the deep and strategic learning approaches.

5.4.2 Inter-relation between the design processes respondents engage in and the quality of their design solutions (RQ 2)

RQ 2: *"What is the inter-relation between students' design processes and the quality of design solutions they produce?"* is addressed in this section. The Spearman's correlation analysis is used to examine the relationship between the design processes respondents engage in (eight variables) and the quality of their design solutions (see Table 5.7). Values of ±.1 represent a small effect. ±.3 is a medium effect and ±.5 is a large effect between the process and outcome level variables (Field, 2013). The total number of considerations that respondents make is significantly correlated to all five outcome scales. Positive and medium effects are found between this process variable and clarity, *r*=.39, *n*=43, *p*=.011; completeness, *r*=.44. *n*=43. *p*=.003, usefulness, *r*=.35, *n*=43, *p*=.021; and originality of solutions, *r*=.30, *n*=43, *p*=.048.

Table 5.7 Spearman's correlations between process and outcome level variables

Process variables	Outcome variables				
	Clarity	Completeness	Usefulness	Feasibility	Originality
1. Total number of considerations	.39*	.44**	.35*	-.32**	.30*
2. No of considerations students commence with	-.04	.08	.05	-.16	-.12
3. No. of specialised topics students considered	.05	.40**	.17	-.24	.16
4. Comprehensiveness of specialised topics considered	.21	.55**	.35*	-.41*	.35*
5. No of phases in design process	.10	.36*	.44**	-.19	.18
6. Comprehensiveness of design activities	.31*	.54**	.64**	-.39**	.34*
7. Number of design activities related to the problem space	.16	.32*	.35*	-.07	.09
8. Number of design activities related to the solution space	-.11	.17	.23	-.31*	.19

**Correlation is significant at p< 0.01.
*Correlation is significant at p< 0.05.

A medium negative effect is found between the total number of considerations that respondents make and feasibility, *r*=-.32, *n*=43, *p*=.036. This means that as respondents made more considerations, the clarity, completeness, usefulness, and originality of their solutions would increase. On the other hand, the feasibility of their solution would also decrease. However, no significant correlations can be found between the number of considerations that respondents make in the beginning of their design process to any of the outcome variables. This means that there is no relationship between the number of considerations that respondents make in the beginning of their design process to the clarity, completeness, usefulness, feasibility and originality of their solutions.

The number of specialised topics that respondents considered are positively and moderately correlated to the completeness of their solutions, r=.40, n=43, p=.008. Furthermore, the more comprehensively respondents considered the specialised topics, their solutions would also be more complete, r=.55, n=43, p=.000; useful, r=.35, n=43, p=.020; and original, r=.35, n=43, p=.021. However, the feasibility r=-.41, n=43, p=.007 of their solutions would also decrease.

The number of phases that respondents engaged in during their design process are moderately and positively correlated to the completeness, r=.36, n=43, p=.014; and usefulness of their solutions, r=.44, n=43, p=.002. Additionally, the comprehensiveness of the design activities that respondents engage in these phases are firstly, strongly and positively correlated to the completeness, r=.54, n=43, p=.000; and usefulness of their solutions, r=.64, n=43, p=.000. Secondly, it is positively and moderately correlated to the originality of solutions, r=.34, n=43, p=.021. Thirdly, it is negatively and moderately correlated to the feasibility of solutions, r=-.39, n=43, p=.009. This means that the more deeply and more comprehensively respondents engaged in their considerations throughout their design process, their solutions would be more complete and useful. Furthermore, the more comprehensively they engage in their considerations of the design problem, their solutions would be more original, but less feasible i.e., more difficult to be implemented.

The number of design activities that respondents engaged in, that is related to the problem space, is moderately and positively correlated to the completeness, r=.32, n=43, p=.034; and usefulness, r=.35, n=43, p=.018; of their solutions. Furthermore, the design activities that respondents engaged in, that are related to the solution space is negatively and moderately correlated to the feasibility of their solutions, r=-.31, n=45, p=.039.

Generally, these results indicate that the clarity, completeness, usefulness and originality of solutions that the respondents produced would increase, as they engaged in their design process more deeply and comprehensively. However, the feasibility of their solutions would also decrease.

5.4.3 Inter-relations between the two mind-sets and design processes (RQ 3)

The first part of RQ 3: *"What is the inter-relation between the two mind-sets and the design processes that they engage in?"* is addressed in this section. A Spearman's correlational analysis is conducted to observe the inter-relations between the two mind-sets and the eight process variables (see Table 5.8). In essence, the Spearman's correlational analysis shows that the discerning mind-set scores are more positively correlated to the process variables. In contrast, opportunistic mind-set scores are more negatively correlated to the process variables.

Table 5.8 Spearman's correlations between presage and process level variables

Process Variables	Presage variables	
	Discerning Mind-set	Opportunistic Mind-set
1. Total number of considerations	.17	-.45**
2. No of considerations students commence with	.07	-.02
3. No. of specialised topics students considered	.31*	-.49**
4. Comprehensiveness of specialised topics considered	.36*	-.54**
5. No of phases in design process	.33*	-.43**
6. Comprehensiveness of design activities	.38*	-.49**
7. Number of design activities related to the problem space	.31*	-.50**
8. Number of design activities related to the solution space	.12	-.01

**Correlation is significant at p< 0.01.
*Correlation is significant at p< 0.05.

Discerning mind-set scores are positively and moderately correlated to five process variables (Variables 3 to 7). This includes the number of specialised topics that respondents considered, *r*=.31, *n*=43, *p*=.046; and the comprehensiveness of these specialised topics considered, *r*=.36, *n*=43, *p*=.019. It also includes the number of phases that respondents engaged in their design process, *r*=.33, *n*=45, *p*=.028; and the comprehensiveness of their design activities. *r*=.38, *n*=45, *p*=.011. Finally, it includes the number of problem space levels that respondents engaged in, *r*=.31, *n*=45, *p*=.037. This means that as respondents rated themselves higher on the discerning mind-set scale, they would not only incline towards considering more specialised topics, but they would also consider these topics more comprehensively. Additionally, respondents would not only engage in more design activities throughout their design process, but they would engage in their design activities more comprehensively. Also, as respondents rated themselves higher on items in the discerning mind-set scale, they would engage in more design activities that are related to the problem space.

Opportunistic mind-set scores are negatively and rather strongly correlated to six of process variables (Variables 1 and 3 to 7). This includes the total number of considerations that respondents made. r=-.45, n=43, p=.002; the number of specialised topics that respondents considered, r=-.49, n=43, p=.001; and the comprehensiveness of these specialised topics considered, r=-.54, n=43. p=.000. It also includes the number of phases that respondents engaged in their design process, r=-.43, n=45, p=.003; and the comprehensiveness of their design activities, r=-.49, n=45, p=.001. Finally, it includes the number of problem space levels that respondents engaged in, r=-.50, n=45, p=.001. This means that as respondents rated themselves higher on items in the opportunistic mind-set scale, the amount of considerations that they make throughout their design process decreases. They would also consider lesser amount of specialised topics and consider these specialised topics less comprehensively. Furthermore, these respondents would engage in a lower number of design activities, and they would engage in their design activities less comprehensively. Finally, as respondents rated higher opportunistic scores, the number of design activities they engage in that are related to the problem space also decreases.

An *Independent T-test* is conducted to compare the different process variables between the two mind-sets (see Table 5.9). Eight process variables are assessed in this analysis. The first four process variables are related to the considerations that respondents make throughout their design process. Respondents clustered in the high discerning and high opportunistic mind-set groups differed on three of these four variables (Variables 1, 3 and 4).

High discerning respondents (M=41.95, SD=22.71) made more considerations compared to opportunistic mind-set respondents (M=28.54, SD=12.01); t(30.01)=-2.42, p=.023. Additionally, high discerning respondents considered more specialized topics related to the problem (M=3.05, SD=1.63) compared to high opportunistic respondents (M=1.68, SD=1.55); t(41)=-2.82; p=.007, and considered the specialized topics more comprehensively (M=2.81, SD=1.17) compared to the high opportunistic respondents (M=1.55, SD=1.30); t(41)=-3.35, p=.002.

The next four process variables are related to the design activities that respondents engaged in. Respondents clustered in the high discerning and high opportunistic mind-set also differed on three of these four variables (Variables 5 to 7). Respondents that inclined towards a high discerning mind-set (M=3.76, SD=1.37) engaged in more design phases compared to respondents that inclined towards a high opportunistic mind-set (*M*=2.67, *SD*=0.96); *t*(43)=-3.13; *p*=.003. They also engaged in their design activities (*M*=10.67, *SD*=5.01) more comprehensively compared to respondents in the high opportunistic cluster (*M*=5.88, *SD*=2.63); *t*(29.29)=-3.93; *p*=.000. Additionally, respondents in the high discerning cluster (*M*=1.91, *SD*=0.99 engaged in more design activities that were related to the problem space compared to respondents in the high opportunistic cluster (*M*=1.00, *SD*=0.78); *t*(43)=-3.42; *p*=.001.

Table 5.9 Comparison between high discerning and high opportunistic mind-set respondents: Process level variables

Scale/Variable	High Discerning mind-set N=21 Mean (SD)	High Opportunistic mind-set N=24 Mean (SD)	Effect size, Cohen's D	Sig. level, *p (two-tailed)*
Regarding considerations				
1. Total number of considerations *	41.95 (22.71)	28.64 (12.01)	0.73	.023
2. No of considerations students commence with [NS]	5.24 (3.24)	4.60 (2.04)	0.24	.435
3. No. of specialized topics students considered **	3.05 (1.63)	1.68 (1.55)	0.86	.007
4. Comprehensiveness of specialized topics considered **	2.81 (1.17)	1.55 (1.30)	1.02	.002
Regarding design activities				
5. No of phases in design process **	3.76 (1.37)	2.67 (0.96)	0.92	.003
6. Comprehensiveness of design activities***	10.67 (5.01)	5.88 (2.63)	1.20	.000
7. Number of design activities related to the problem space **	1.91 (0.99)	1.00 (0.78)	1.02	.001
8. Number of design activities related to the solution space [NS]	1.86 (0.96)	1.67 (0.70)	0.23	.449

[NS] T-test on average scores over two clusters was not significant.
*T-test on average scores over two clusters was significant at p<0.05.
**T-test on average scores over two clusters was significant at p<0.01.
***T-test on average scores over two clusters was significant at p<0.001.

Large effect sizes ranging from Cohen's *d*, 0.73 to 1.20 can be found for the six variables. This indicates the large differences between the high discerning and high opportunistic clusters with regards to these process variables. However, the number of considerations that respondents considered at the beginning of their design process, and the number of activities they engaged in that relate to the solution space were not significantly different between the two mind-set groups.

5.4.4 Relation between mind-sets and design processes when receiving and not receiving reflection-oriented stimuli (RQ 3)

The second part of RQ 3: *"Are there differences between discerning and opportunistic mind-set students, in terms of their design processes, when they are introduced to reflection-oriented stimuli?"* is addressed in this section (quantitative data) and the following section (qualitative data). A *One-way ANOVA* is used to compare the differences between respondents in the high discerning and high opportunistic mind-set clusters, that either received or did not receive any stimulus, respectively. Comparisons are made to see whether respondents within these clusters engage in their design processes differently when they are introduced to reflection-oriented stimuli as discussed in Section 5.3.3 (see Table 5.10).

Three significant differences related to respondents in the opportunistic mind-set group that did not receive the reflection-oriented stimuli can be found. Firstly, they considered a significantly lower number of specialised topics related to the design problem (M=1.30, SD=1.34), compared to respondents in the discerning mind-set group that received the reflection-oriented stimuli (M=3.40, SD=1.58), $F(3,39)$=3.31, p=.030. Secondly, they considered the specialised topics less comprehensively (M=1.20, SD=1.14) compared to respondents in the discerning mind-set group that did not receive the reflection-oriented stimuli (M=2.91, SD=1.14), $F(3,39)$=4.22, p=.011. Thirdly, they engaged in their design activities less comprehensively (M=5.27, SD=2.80) compared to respondents in the discerning mind-set group that did not receive the reflection-oriented stimuli (M=11.18, SD=5.02), $F(3,41)$=5.71, p=.002.

Three significant differences related to respondents in the opportunistic mind-set group that received the reflection-oriented stimuli can also be found. The ANOVA showed that these respondents engaged in a lesser number of design phases in their design process (M=2.62, SD=0.96) and secondly, engaged in their design activities in a less comprehensive manner (M=6.38, SD=2.47) compared to respondents in the discerning mind-set group that did not receive the reflection-oriented stimuli (M=4.00, SD=1.55), $F(3,41)$=3.51, p=.024; (M=11.18, SD=5.02), $F(3,41)$=5.71, p=.002. Thirdly, they engaged in a lesser number of design activities related to the problem space (M=0.77, SD=0.83), compared to respondents in the discerning mind-set group that received the reflection-oriented stimuli (M=1.80, SD=1.03), F(3, 41)=4.64, p=.007, and that did not receive the reflection-oriented stimuli could (M=1.80, SD=1.03), F(3,41)=4.64, p=.007.

Table 5.10 Comparison of design processes between high discerning and high opportunistic mind-set respondents when receiving and not receiving reflection-oriented stimulus

Process level variables	High Opportunistic Cluster		High Discerning Cluster		Post-hoc comparison (Bonferroni)
	C1 Without stimulus Mean (SD) N=11	C2 With Stimulus Mean (SD) N=13	C3 Without stimulus Mean (SD) N=11	C4 With Stimulus Mean (SD) N=10	
Regarding considerations					
1. Total number of considerations [NS]	24.10 (11.56)	32.42 (11.47)	43.45 (23.33)	40.30 (23.15)	n/a
2. No of considerations students commence with [NS]	4.40 (1.96)	4.75 (2.18)	5.36 (2.84)	5.10 (3.78)	n/a
3. No. of specialised topics students considered *	1.30 (1.34)	2.00 (1.71)	2.73 (1.68)	3.40 (1.58)	C1 < C4
4. Comprehensiveness of specialised topics considered *	1.20 (1.14)	1.83 (1.40)	2.91 (1.14)	2.70 (1.25)	C1 < C3
Regarding design activities					
5. No of phases in design process *	2.73 (1.01)	2.62 (0.96)	4.00 (1.55)	3.50 (1.18)	C2 < C3
6. Comprehensiveness of design activities * *	5.27 (2.80)	6.38 (2.47)	11.18 (5.02)	10.10 (5.22)	C1 < C3, C2 < C3
7. Number of design activities related to the problem space **	1.27 (0.65)	0.77 (0.83)	2.00 (1.00)	1.80 (1.03)	C2 < C3, C2 < C4
8. Number of design activities related to the solution space [NS]	1.45 (0.69)	1.85 (0.69)	2.00 (0.89)	1.70 (1.06)	n/a

[NS] One-way ANOVA test on average scores over two clusters was not significant.
* One-way ANOVA test on the average scores over the four clusters was significant at $p<0.05$.
** One-way ANOVA test on the average scores over the four clusters was significant at $p<0.01$.

5.4.5 Relation between mind-sets and design processes: Qualitative description between respondents that received and did not receive reflection-oriented stimuli (RQ 3)

The graphical output produced by respondents (see Section 5.3.2) were also qualitatively analysed to answer the second part of RQ 3: *"Are there differences between discerning and opportunistic mind-set students, in terms of their design processes, when they are introduced to reflection-oriented stimuli?"*. The *considerations network* (CN) (see Section 5.3.6) of respondents that did and did not receive the reflection-oriented stimuli from the two mind-set groups were also examined (see Figure 5.12 and Figure 5.13). These figures illustrate examples of *CN's* for respondents categorised in the high discerning and high opportunistic groups respectively. Typical examples of respondents' *CNs* when they received and did not receive the reflection-oriented stimuli, and when they made high and low numbers of considerations are presented. When the number of considerations that respondents made fell below the mean value (M=35.14, SD=19.05), they were clustered as making a low number of considerations. In addition, when the number of considerations they made were above the mean value, they were clustered as making high numbers of considerations.

In the high discerning cluster, no differences can be observed between respondents that received and did not receive the reflection-oriented stimuli. On average, respondents that made a high number of considerations made around 60 considerations. Respondents that made a low number of considerations made around 20 considerations. Similarly, in the high opportunistic mind-set cluster, no differences can be observed between respondents that received and did not receive the reflection-oriented stimuli. On average, respondents that made a high number of considerations made around 50 considerations. Respondents that made a low number of considerations made around 20 considerations. This suggests that within both high discerning and high opportunistic mind-set groups, respondents would make approximately the same low or high amount of considerations. The reflection-oriented stimuli did not affect the number of considerations that they would make.

A comparison between the number of high discerning and high opportunistic mind-set respondents, when receiving and not receiving reflection-oriented stimulus, however, reveals an interesting result (see Table 5.11). Out of 21 respondents grouped in the high discerning cluster, 11 respondents did not receive the reflection-oriented stimuli while 10 respondents did. Out of the 22 respondents grouped in the high opportunistic cluster, 10 respondents did not receive the reflection-oriented stimuli

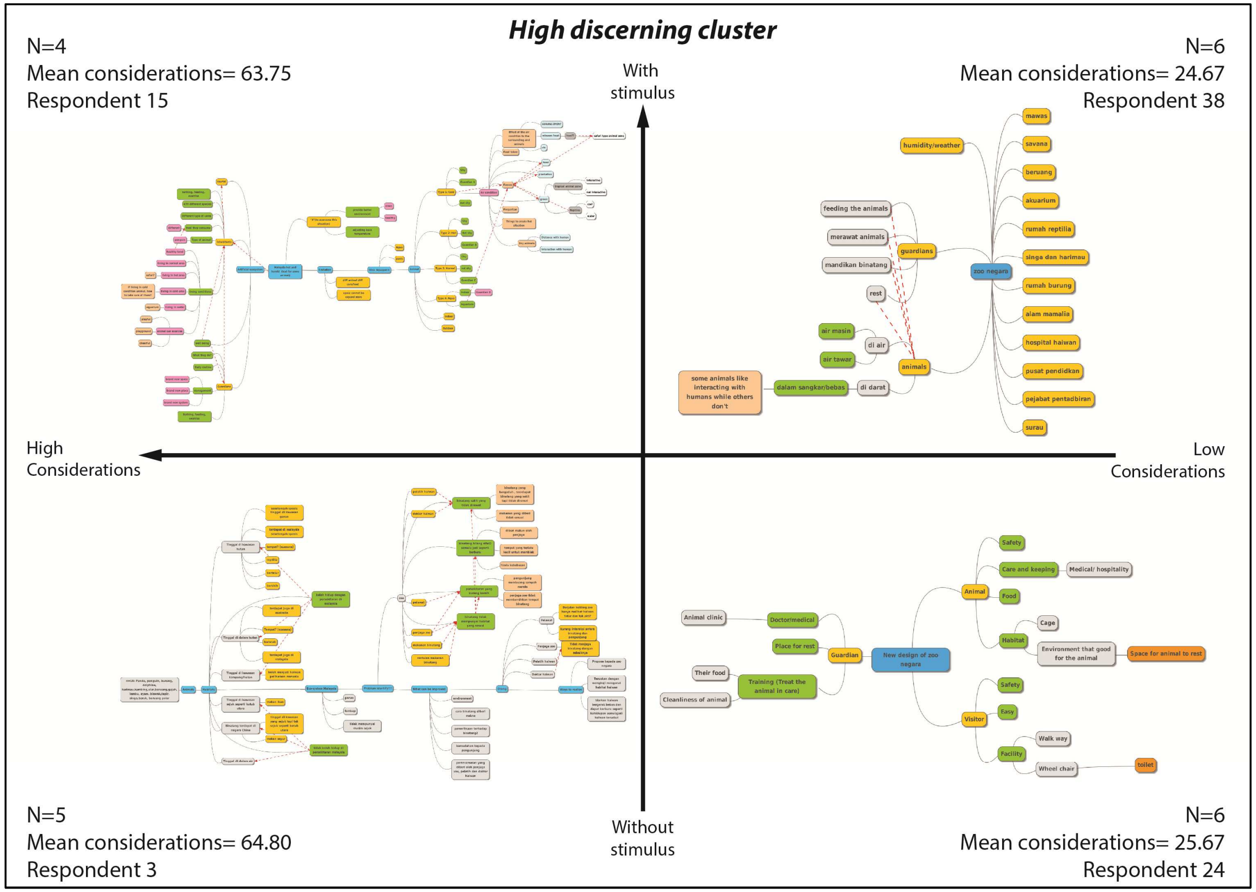

Figure 5.12 Considerations network of high discerning respondents that receive and do not receive stimulus

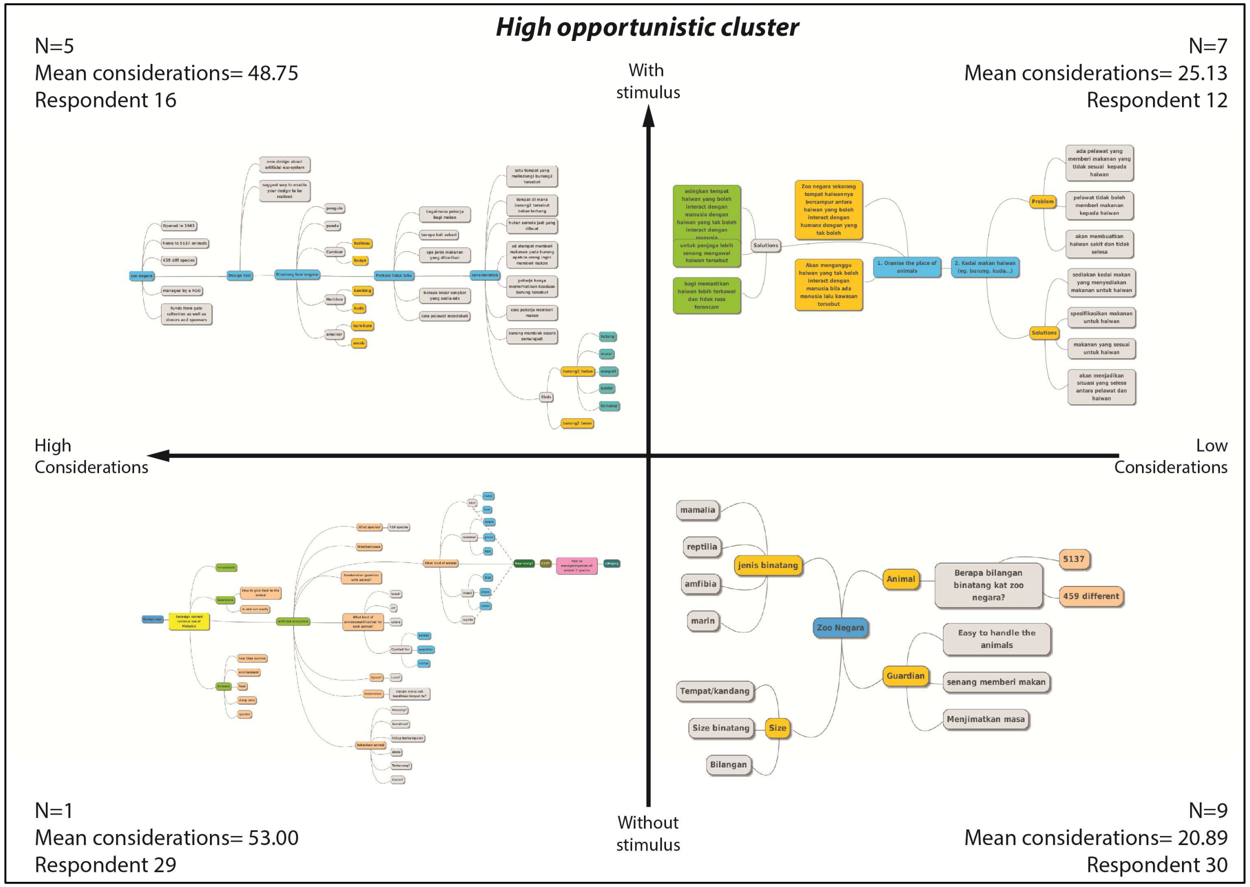

Figure 5.13 Considerations network of high opportunistic respondents that receive and do not receive stimulus

Table 5.11 Comparison between the number of high discerning and high opportunistic mind-set respondents, when receiving and not receiving reflection-oriented stimulus: Chances of respondents making a high number of considerations

Receive stimulus?	NO (Without Stimulus)				YES (With Stimulus)			
Mind-set cluster	**High Discerning**		**High Opportunistic**		**High Discerning**		**High Opportunistic**	
No of respondents	11 respondents out of 21 high discerning respondents		10 respondents out of 22 high opportunistic respondents		10 respondents out of 21 high discerning respondents		12 respondents out of 22 high opportunistic respondents	
Level of considerations made	Low	High	Low	High	Low	High	Low	High
No of respondents	6	5	9	1	4	6	5	7
Percentage within mind-set cluster	55%	45%	90%	10%	40%	60%	41%	59%
Chances of making a high number of considerations	Approximately equal chances		Low chances		Approximately equal chances			

while 12 respondents did. The comparison reveals that respondents inclining toward a high discerning mind-set have approximately equal chances of making a high number of considerations. 45% of respondents that did not receive the reflection-oriented stimuli made a high number of considerations. However, although the percentage of respondents making a high number of consideration increases to 60% when they did receive the reflection-oriented stimuli, these values are roughly comparable.

The comparison further reveals that high opportunistic respondents have a lower chance of making a high number of considerations when they are not introduced to the reflection-oriented stimuli. Only one respondent in the high opportunistic group, that did not receive the reflection-oriented stimuli, made a high number of considerations. This accounts for only 1 respondent within the high opportunistic cluster that made a high number of considerations. The remaining nine respondents made a low number of considerations. On the other hand, when respondents in the high opportunistic cluster did receive the reflection-oriented stimuli, 59% of the respondents made a higher number of considerations, compared to the remaining 41% that did not. In other words, the likelihood of respondents that incline toward a high opportunistic mind-set to make more considerations throughout their design process increases when they receive reflection-oriented stimuli.

To validate the qualitative findings, an *Independent T-test* was conducted to validate the differences between respondents in the high opportunistic group that did and did not receive the reflection-oriented stimuli. This analysis shows that respondents that received the stimuli (M=36.94, SD=14.06) made a significantly higher number of considerations compared to respondents that did not receive the reflection-oriented stimuli (M=25.50, SD=10.51), $t(26)=-2.36$, $p=.026$, $F(26, 25.99)=2.395$, $p=.134$. A high sample effect size of Cohen's $d=0.92$ can be observed for this analysis. This indicates the large differences between the two clusters that received and did not receive the reflection-oriented stimuli. This analysis reveals that respondents in the high opportunistic mind-set cluster indeed made more considerations throughout their design process, when they received the reflection-oriented stimuli, as opposed to when they did not receive the reflection-oriented stimuli.

5.4.6 Inter-relation between the two mind-sets and the quality of design solutions produced (RQ 4)

The first part of RQ 4: "What is the inter-relation between the two mind-sets and the quality of design solutions that they produce?" is addressed in this section. An independent T-test is conducted to compare the outcome level variables between the high discerning and high opportunistic mind-set clusters. Three significant differences between the two clusters can be observed (see Table 5.12). Respondents in the high discerning mind-set cluster (M=3.69, SD=0.78) produced solutions with higher clarity compared to respondents in the high opportunistic mind-set cluster (M=2.92, SD=0.94), t(43)=-2.98, p=.005. Additionally, respondents in the high discerning mind-set cluster (M=2.98, SD=0.66) produced solutions with higher completeness compared to respondents in the high opportunistic mind-set cluster (M=2.27, SD=0.71), t(43)=-3.44, p=.001.

Table 5.12 Comparison between discerning and opportunistic mind-set students: Outcome level variables

Scale/Variable	Discerning mind-set N=21	Opportunistic mind-set N=24	Effect size, Cohen's D	Significance level, *p* *(two-tailed)*
Clarity **	3.69 (0.78)	2.92 (0.94)	0.89	.005
Completeness **	2.98 (0.66)	2.27 (0.71)	1.04	.001
Usefulness **	3.71 (0.62)	3.02 (0.80)	0.96	.003
Feasibility [NS]	3.64 (0.71)	3.92 (0.65)	0.41	.185
Originality [NS]	2.21 (0.82)	1.96 (0.67)	0.33	.255

[NS] T-test on average scores over two clusters was not significant
** Independent T- test on the average scores over the two clusters significant at p<0.01.

Respondents in the high discerning mind-set cluster (M=3.71, SD=0.62) also produced solutions with higher clarity compared to respondents in the high opportunistic mind-set cluster (M=3.02, SD=0.80), t(43)=-3.21, p=.003. An analysis of the sample effect sizes reveal large effects for the three outcome scales, Cohen's *d*=0.89 to 1.04. These large effect sizes indicate the big differences between the high discerning and high opportunistic mind-set clusters in terms of the clarity, completeness and usefulness of solutions that they produced.

5.4.7 Relation between mind-sets and design outcomes when receiving and not receiving reflection-oriented stimuli (RQ 4)

The second part of RQ 4: *"Does the quality of design solutions differ between discerning and opportunistic mind-set students when they are introduced to reflection-oriented stimuli?"* is addressed in this section. A *One-way ANOVA* is used to compare differences within respondents in the high discerning and high opportunistic mind-set clusters that received and did not receive any stimulus (see Table 5.13). Comparisons are made to see whether respondents within these clusters produced better design outcomes when they are introduced to the reflection-oriented stimuli as discussed in Section 5.3.3. The Bonferroni post-hoc tests were used to compare all the different combinations of the control and experimental groups

Table 5.13 Comparison of design outputs between high discerning and high opportunistic mind-set respondents when receiving and not receiving reflection-oriented stimulus

Product level variables	High Opportunistic Cluster		High Discerning Cluster		Post-hoc comparison (Bonferroni)
	C1 Without stimulus Mean (SD) N=11	C2 With Stimulus Mean (SD) N=13	C3 Without stimulus Mean (SD) N=11	C4 With Stimulus Mean (SD) N=10	
Regarding considerations					
1. Clarity **	2.91 (1.04)	2.92 (0.89)	3.77 (0.52)	3.60 (1.02)	C2 < C3
2. Completeness ***	2.41 (0.77)	2.15 (0.66)	3.14 (0.74)	2.80 (0.54)	C2 < C3
3. Usefulness **	3.00 (1.00)	3.04 (0.63)	3.77 (0.65)	3.65 (0.63)	C2 < C3
4. Feasibility **	4.32 (0.51)	3.58 (0.57)	3.55 (0.76)	3.75 (0.68)	C1 >C2, C1 >C3
5. Originality [NS]	2.00 (0.74)	1.92 (0.64)	2.45 (0.85)	1.95 (0.72)	n/a

[NS] One-way ANOVA test on average scores over two clusters was not significant.
* One-way ANOVA test on the average scores over the four clusters was significant at $p<0.05$.
** One-way ANOVA test on the average scores over the four clusters was significant at $p<0.01$.

(Field, 2013). This analysis reveals that firstly, respondents in the high discerning mind-set group that did not receive any stimulus produced solutions that had higher clarity (M=3.77, SD=0.52), completeness (M=3.14, SD=0.74) and usefulness (M=3.77, SD=0.65), compared to the respondents in the high opportunistic mind-set group that received the reflection-oriented stimuli (M=2.92, SD=0.89), F(3,41)=2.89, p=.047; (M=2.15, SD=0.66), F(3,41)=4.65, p=.007; (M=3.04, SD=0.63), F(3,41)=3.33, p=.029. Next, respondents in the high opportunistic mind-set cluster that did not receive the reflection oriented stimuli (M=4.32, SD=0.51) produced solutions that were more feasible i.e., were less complicated or difficult to implement. This is compared to respondents in the high opportunistic cluster that received the reflection-oriented stimuli (M=3.58, SD=0.57), F(3,41)=3.61, p=.021 and the high discerning mind-set cluster that did not receive the reflection-oriented stimuli (M=3.55, SD=0.76), F(3,41)=3.61, p=.021. In addition, no significant differences can be observed in terms of the originality of solutions produced F(3,41)=1.28, p=.293. This means that the originality of solutions produced were approximately equivalent across all respondents.

5.5 Discussion

Considerable differences can be observed between respondents that were grouped into the high discerning and high opportunistic mind-set clusters. These differences are discussed in the following sub-sections. Firstly, the preferred learning approaches of the two mind-set types and their engagement in the design process are discussed. Secondly, the two mind-set types and the quality of solutions they produce are discussed. Thirdly, the discussion relates to the design processes of the two mind-set clusters when respondents receive and do not receive the reflection-oriented stimuli. Fourthly, the relation between the design processes respondents engaged in and the quality of their design solutions are discussed. Finally, the quality of solutions produced by respondents from the two mind-sets clusters, when respondents receive and do not receive the reflection-oriented stimuli are discussed.

5.5.1 Mind-sets and preferred learning approaches

Mind-sets are expected to influence the internal mental dispositions and external behavioural responses that students adopt in design learning (Hamat et al., 2015). In terms of internal mental disposition, this study reveals that design students within the high discerning mind-set cluster have a preference for deep and strategic approaches in learning design. This preference was in contrast to the preference of students in the high opportunistic mind-set cluster. The deep learning approach is related to being highly engaged in design tasks or projects and an inclination towards seeking meaning between concepts. It also relates to connecting ideas and information, and using corroborative evidence to support the development of design ideas and/or decisions.

These inclinations further manifest within the design process that discerning mind-set respondents engage in, which encompasses their behavioural responses.

5.5.2 Mind-sets and design processes

An inclination toward a high discerning or opportunistic mind-set have been found to influence the consideration that students make and the design activities that they engage in throughout their design process. Firstly, students in the high discerning mind-set cluster showed more considerations throughout their design process. Secondly, they considered more specialised topics related to the design problem and thirdly, they considered the topics comprehensively. Students in the high opportunistic mind-set cluster engaged in these three aspects of their design process contrastingly. They made lesser considerations, and considered lesser and less comprehensively, specialised topics related to the design problem.

Students in the high discerning mind-set cluster also engaged in more steps/design activities in their design process. They also engaged in their design activities more comprehensively compared to respondents in the high opportunistic mind-set cluster. Further differences can be observed between the high discerning and high opportunistic mind-set clusters in terms of the type of design space that they engage in throughout their design process. Students in the high discerning mind-set cluster engaged in more design activities related to the problem space, compared to respondents in the high opportunistic mind-set cluster. In terms of engagement in the solution space however, both mind-set clusters spend approximately an equivalent number of design activities. The differences between the high discerning and high opportunistic clusters in relation to their design process are summarized in the following illustration (see Figure 5.14).

Design students inclining toward a high discerning mind-set were found to tolerate ambiguity in problem solving situations (see Section 4.3.2 in Chapter 4). In this study, the behavioural responses of how high discerning mind-set students deal with ambiguity can be observed when they are posed with an unfamiliar design task. The results strongly indicate that respondents that incline toward a high discerning mind-set will engage more actively i.e., more broadly and deeply in their design processes. They are more likely to immerse themselves in understanding the context of complex and ambiguous design problems prior to working out a solution.

Respondents inclining toward an opportunistic mind-set can tolerate ambiguity in interpersonal related situations i.e., social communication between persons (see Section 4.3.2 in Chapter 4). By accepting ambiguity in interpersonal communication, this also means that high opportunistic mind-set students avoid conflicts that may arise in situations. The results in this study further supports this notion. When faced

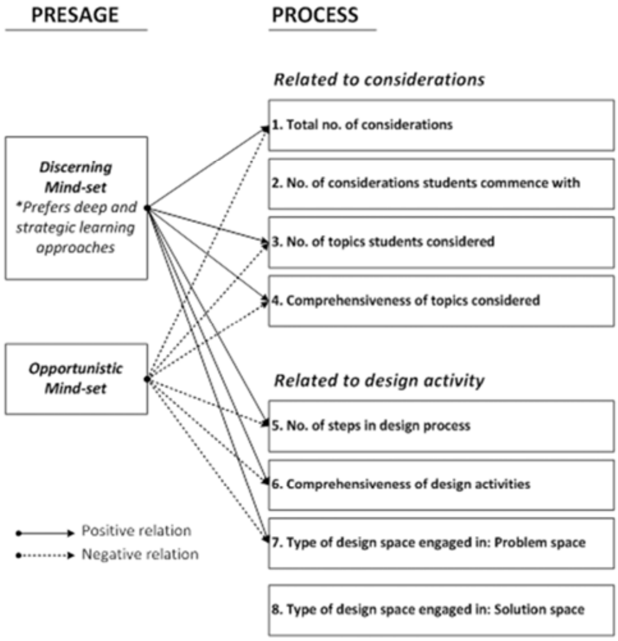

Figure 5.14 Between discerning and opportunistic mind-set respondents: Their preferred learning approaches and design processes

with the unfamiliar design task, respondents inclining toward a high opportunistic mind-set precipitate toward avoiding ramifications that are necessary to explore the design task. They engaged in their design process on a shallow level and are more likely to explore a restricted range of topics or issues related to the design problem.

5.5.3 Mind-sets and design processes: Effects of reflection-oriented stimuli

Reflection through question-asking is advocated to improve design processes (Dym et al., 2005; Reymen, 2001). This method was adapted in the reflection-oriented stimuli used in this study. Findings from this study continues to support this notion. An increase in terms of the amount of considerations that the design students made throughout their design process can be observed within the high opportunistic and high-discerning mind-set clusters. However, the increase was much higher within the high opportunistic mind-set cluster. A 49% increase could be observed (see Table 5.11). This indicates the considerable opportunities of improving design processes of students inclining toward a high opportunistic mind-set.

The increase within the high discerning mind-set cluster was not strikingly apparent. Only a non-significant increase of 15% could be observed. However, this could be due to the fact that students within the high discerning mind-set cluster were already engaged in their considerations and design activities at a high level. Thus the increase in engagement when they did receive the reflection-oriented stimuli was less observable. However, students in the high discerning mind-set cluster did engage in more design activities related to the problem space when they received the stimuli. Furthermore, students in the high discerning cluster were engaged in their considerations and design activities more comprehensively compared to students in the high opportunistic cluster (see Table 5.14).

Table 5.14 Effects of reflection-oriented stimulus on process-level variables between high discerning and high opportunistic mind-set respondents based on One-way ANOVA (↑=higher, ↓=lower)

Process variables	High opportunistic mind-set		High discerning mind-set	
	With stimulus	Without stimulus	With stimulus	Without stimulus
1	–	–	–	–
2	–	–	–	–
3	–	↓	↑	–
4	–	↓	–	↑
5	↓	–	–	↑
6	↓	↓	–	↑
7	↓	–	↑	↓
8	–	–	–	–

Process variables:
1. Total number of considerations
2. No of considerations students commence with
3. No. of specialised topics students considered
4. Comprehensiveness of specialised topics considered
5. No of phases in design process
6. Comprehensiveness of design activities
7. Number of design activities related to the problem space
8. Number of design activities related to the solution space

Firstly, students in the high opportunistic cluster that did not receive the stimuli considered a significantly lower number of specialised topics related to the design problem compared to the high discerning cluster that received the stimuli. Secondly, they considered the specialised topics less comprehensively and were engaged in their design activities less comprehensively compared to students in the high discerning cluster that did not receive the stimuli. Thirdly, students in the high opportunistic mind-set cluster that did receive the stimuli were engaged in a lesser of number design activities and they were engaged in these design activities less comprehensively. This is compared to the high discerning mind-set cluster that did not receive the stimuli. Lastly, students in the high opportunistic mind-set cluster that did receive the stimuli were engaged in a lesser of number of design activities related to the problem space. This is compared to students in the high discerning mind-set cluster that received the stimuli.

These findings provide compelling evidence to indicate that the reflection-oriented stimuli had beneficial effects on the considerations and design activities of respondents in both the high discerning and high opportunistic mind-set clusters. These effects were strikingly observable within the high opportunistic mind-set cluster. These results confer potential implications for design teaching and learning. Evidence shows that the encouragement of reflection through question-asking can promote positive behavioural effects within design students, even within students that incline toward a high opportunistic mind-set. Ultimately, how do these process-related variables relate to the quality of solutions that respondents produce i.e., the outcome? These aspects are further discussed in the following section.

5.5.4 Design process and quality of design solutions

Behavioural variables have been found to affect outcomes in learning (Armor & Taylor, 2003; Burnette et al., 2013; Zeng et al.,2016). This notion is further supported by findings in this study (see Table 5.15). The interaction between students' design process and quality of design solutions were analysed by correlating the process and product-level variables. In general, it can be observed that as the comprehensiveness of considerations and engagement in design activities increased, the quality of solutions also increased.

The completeness and usefulness of solutions increased when students engaged in more design activities in their design process, engaged in their design activities and considerations on specialised topics related to the design problem more comprehensively, and engaged in more design activities related to the problem space. The solutions produced would solve the problem more thoroughly and better benefit the stakeholders involved in the design problem. The completeness of solutions also increased when students considered more specialised topics related to the design problem. The solutions produced solved the problem more thoroughly. Additionally, the originality and clarity of solutions also increased when students were more comprehensively engaged in their design activities. The solutions were more interesting and different compared to other solutions and were communicated in a better way. Furthermore, the originality of solutions increased when specialised topics were considered more comprehensively.

Table 5.15 Connection between process variables to outcome variables (↑=higher, ↓=lower)

Process variables	Clarity	Completeness	Usefulness	Feasibility	Originality
1	↑	↑	↑	↓	↑
2	–	–	–	–	–
3	–	↑	–	–	–
4	–	↑	↑	↓	↑
5	–	↑	↑	–	–
6	↑	↑	↑	↓	↑
7	–	↑	↑	–	–
8	–	–	–	↓	–

Process variables:
1. Total number of considerations
2. No of considerations students commence with
3. No. of specialised topics students considered
4. Comprehensiveness of specialised topics considered
5. No of phases in design process
6. Comprehensiveness of design activities
7. Number of design activities related to the problem space
8. Number of design activities related to the solution space

The feasibility of solutions, however, decreased as the comprehensiveness of considerations and design activities increased. As the clarity, completeness, usefulness and originality of solutions increased, the solutions produced became less feasible i.e., more difficult to implement. The feasibility of solutions decreased when respondents made more considerations, considered on specialised topics related to the design problem more comprehensively, engaged in their design activities more comprehensively, and engaged in more design activities related to the solution space.

These results strongly suggest that as design students increase the considerations and design activities that they engage in, and when they do this more comprehensively, the clarity, completeness, usefulness, and originality of their solutions will also increase. However, the feasibility of solutions that they produce may also decrease. Important to realise is that the students were given a short amount of time to work on this design task. Thus, it stands to reason that the solutions may lack feasibility. The feasibility, i.e., the ease of implementation of a solution, denotes an ensuing step to be considered in the design process and requires more time to be properly incorporated into a solution. The limited amount of time provided within the period of the experiment was probably not sufficient for the application of this additional step. Therefore, the relation found was due to lack of time, not due to the students' ability.

5.5.5 Mind-sets and quality of design solutions

A focus on improving one's own competence and drive to acquire new knowledge have been found to influence outcomes positively (Miller et al., 1993). On the other hand, the tendency to avoid work has been related to poor performance achievements (Harackiewicz et al.,1997). Comparably, these notions relate to the high discerning and high opportunistic mind-sets. Individuals with a high discerning mind-set have a deep interest in knowledge and will actively reflect and experiment in their design activities. Individuals with a high opportunistic mind-set takes convenient measures and administering routine actions. They will also adopt strategies or engage in activities that are easily accessible to them, and they will also avoid undesirable or difficult situations (Hamat et al., 2015, 2016).Thus the notions on the interaction of mind-sets to the quality of outcomes produced by previous studies can be supported by findings in this study.

Design students that inclined toward a high discerning mind-set produced design solutions with better quality compared to those that inclined toward a high opportunistic mind-set, on three out of five scales related to quality. Quality in this study was assessed on five sub-scales. This encompasses the clarity, completeness, usefulness, feasibility and originality of solutions. The three scales that design students with high discerning mind-sets scored better on, compared to their counterparts that inclined toward a high opportunistic mind-set were clarity, completeness and usefulness.

Design solutions produced by those that inclined toward a high discerning mind-set were firstly, communicated well and could be easily understood. In contrast, solutions produced by design students that inclined toward a high opportunistic mind-set were evaluated as having a low degree of clarity. They were more likely to communicate their solutions in an ambiguous or incoherent way. The design solutions produced by high discerning students were more complete. Their solution were considered more likely to thoroughly solve the design problem. Design students that inclined toward a high opportunistic mind-set on the other hand, produced solutions that had a low degree of completeness. Their solutions were more likely to solve unrelated problems or solve the related problem to only a small degree.

The design solutions produced by students that inclined toward a high discerning mind-set were more useful. Their solutions would contribute considerable benefits to stakeholders involved in the design problem. In contrast, design students that inclined toward a high opportunistic mind-set produced design solutions that have a low degree of usefulness. Their solutions would more likely pose disadvantages to the stakeholders involved. In terms of the feasibility and originality of solutions, no significant differences between the two clusters of mind-sets could be observed.

5.5.6 Mind-sets and quality of design solutions: Effects of reflection-oriented stimuli

Interactions between mind-sets and outcome variables are expected to be mediated by process variables (Armor & Taylor, 2003; Burnette et al., 2013; Zeng, Hou, & Peng, 2016). This means that significant differences in terms of outcomes are only expected to be noticeable between behavioural and outcome variables. Interestingly, direct relations between mind-sets and outcomes can be observed within this study. This respectively refers to variables related to the design process that students engage in and the quality of design solutions that they produce (see Figure 5.15).

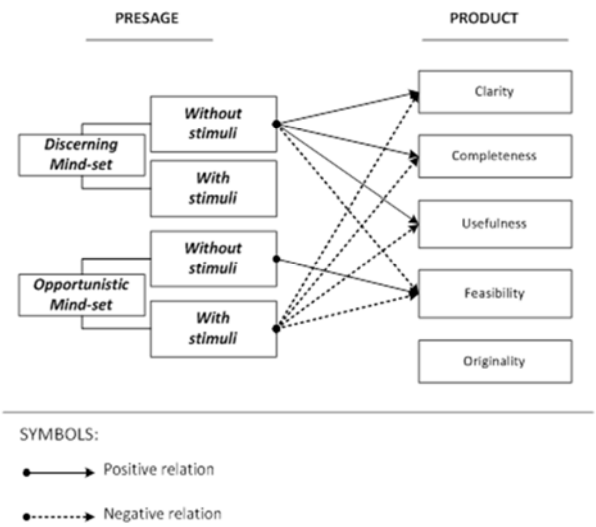

Figure 5.15 Mind-sets and outcomes: Differences within and between the mind-sets, with and without stimuli.

Significant differences could be observed between the high discerning mind-set cluster without stimuli and the high opportunistic mind-set cluster with stimuli. Solutions produced by design students in the high discerning mind-set cluster that did not receive stimuli had higher clarity, completeness and usefulness. This means that their solutions were communicated well and were easily understood; would more thoroughly solve the design problem; and would considerably benefit the stakeholders involved in the design problem. This is in contrast to the quality of solutions produced by design students within the high opportunistic mind-set cluster that did not receive any stimuli.

The solutions they produced were ambiguously and incoherently communicated; are less likely to solve the given design problem; and posed to be disadvantageous to the stakeholders involved in the design problem. These differences indicate that even though students do not receive any form of stimuli, when they incline toward a high discerning mind-set, they would have better chances of coming up with solutions that are more complete, useful and furthermore, be communicated with higher clarity. Compared to students that inclined toward a high opportunistic mind-set, even when they received the reflection-oriented stimuli, the clarity, completeness and usefulness of their solutions were still lower compared to those in the high discerning cluster. However, adverse differences can be observed within the high discerning mind-set cluster when the students received the stimuli. The feasibility of their solutions did not differ compared to students within the high opportunistic mind-set cluster. Conversely, the feasibility of solutions produced by students within the high opportunistic mind-set cluster that received the stimuli and those of students within the discerning mind-set cluster that did not receive any stimuli were significantly different, compared to the feasibility of solutions produced by students within the high opportunistic mind-set cluster that did not receive the stimuli.

Design students in the high opportunistic mind-set cluster without stimuli were found to produce solutions that were more feasible compared to those in the high discerning cluster without stimuli and high opportunistic mind-set cluster with stimuli. Feasibility in this study refers to the degree to which a solution can easily be produced or implemented. Thus, results from this study indicate that when students inclined toward a high opportunistic mind-set and do not receive any form of stimuli, they produced solutions that can be easily implemented or produced. Their solutions would not require drastic modifications from the existing facilities or complicated requisitions in terms of manufacturing and technological advances. This suggests that their solutions less sophisticatedly differs from the existing conditions within the design problem, and are less complex.

Comparisons to observe the direct effects of mind-sets on the quality of solutions that design students produced revealed another interesting result. Outcomes produced by students inclining toward a high opportunistic mind-set can be improved when they are exposed to reflection-oriented stimuli. When they received the reflection-oriented stimuli, their solutions substantially increased in complexity. This provides compelling evidence that the quality of outcomes can be increased within design students that incline toward a high opportunistic mind-set. If the effects of the reflection-oriented stimuli can be generalised to any other form of stimulation within design learning, these results indicate that students within the high opportunistic mind-set cluster would be susceptible to instigation within design learning, and as such can be trained to be better designers.

5.6 Conclusion

Differences between the discerning and opportunistic mind-sets were tested on the presage, process and product levels. Distinct differences between the two mind-sets were found, supporting for the adoption of discerning mind-sets in design learning and more generally, designing. These differences are concluded.

In examining RQ 1 which addresses the preferences of discerning and opportunistic mind-sets in relation to their learning approaches (presage level), results indicate that high discerning mind-set students preferred deep and strategic learning approaches in design learning. High opportunistic students, on the other hand, indicated a significantly lower preference for the deep and strategic learning approaches. This means that high discerning students would prefer to seek for meaning between concepts, relate ideas and information, and use corroborative evidence to support the development of design ideas and/or decisions, but the high opportunistic mind-set students would not.

In examining RQ 2 which addresses the relation between students' design process (process level) and the quality of design solutions that they produced (product level), the correlational analysis shows that students would produce solutions that had higher clarity, completeness, usefulness and originality when they deeply and comprehensively engaged in their design activities. However, feasibility of their solutions would also decrease. The decrease in feasibility of solutions can be expected. It was similarly observed within other experimental studies (Dean et al., 2006). As students engaged more actively in their design considerations and design activities, they are more likely to produce highly rare, new and surprising solutions that more thoroughly solved the design problem and better benefitted the stakeholders involved, and communicate their solutions better. However, as the experiments were conducted in a short and limited amount of time, it can be expected that their solutions would be more difficult to implement as they develop more complex ideas. Nevertheless, it can be expected that high discerning students could also create more feasible solutions, if they were given more time.

In examining RQ 3 which addresses the relation between the two mind-sets (presage level) and design processes (process level), this study shows that high discerning mind-set students engaged more actively in their design considerations and design activities compared to high opportunistic mind-set students (see Table 5.9 for the specific process related variables). Nevertheless, when high opportunistic mind-set students received the reflected oriented stimuli, the number of considerations that they made increased. They also thought of more specialised topics related to the design problem. When high discerning mind-set students received the stimuli, they engaged in more design activities throughout their design process, engaged in their design activities more comprehensively and engaged in more design activities related to the problem space, compared to the high opportunistic mind-set cluster that received the stimuli.

In examining the direct relation between the two mind-sets (presage level) and the design solutions that students produced (product level) (RQ 3), this study shows that high discerning mind-set students produce solutions that have higher clarity, completeness and usefulness compared to high opportunistic mind-set students. Even when high discerning mind-set students did not receive the stimuli, they produced better quality solutions compared to high opportunistic mind-set students that received the stimuli. Additionally, high opportunistic students that did not receive stimuli produced solutions that were more feasible compared to high discerning mind-set students that received and did not receive stimuli. Highly feasible solutions are less complex, less sophisticated, and do not require much changes from existing conditions in the design problem. These findings strongly suggest the advantage in adopting a discerning mind-set within design learning.

Compelling evidence for the promotion of discerning mind-sets within design students have been presented in this study. Students with high discerning mind-sets have been found to show, throughout their design process, higher engagement and comprehensiveness in terms of their considerations and design activities. Furthermore, these behaviours have been found to positively affect the outcomes that students produce. Nevertheless, results from this study also reveal that students that incline toward an opportunistic mind-set can be stimulated to enhance their behaviour in learning. This in turn provides better possibilities of improving their learning outcomes. However, better pedagogical approaches in design learning should be further researched upon to build upon the characteristics of both the discerning and opportunistic mind-sets that prevail within design students. Some studies have looked into the teaching approaches to teachers (Gow & Kember, 1993; Trigwell et al., 1999; Trigwell & Prosser, 2004; Richardson, 2005). However, these studies examine the presage level aspects of teaching. Whereas more studies in the context of a process-level aspect should be further researched upon. This study paves the way for further research on the types of pedagogical approaches to enhance the design learning experience for design students.

6

Discussion and Conclusion

In design education, factors related to both teacher and student affect the outcomes that a student achieves. Teachers play a role in students' learning by transferring knowledge to their students. This knowledge is commonly based on pre-defined course structures that are offered by the specified design programmes. However, student–related factors are expected to play a more pivotal role in enabling students to manage their own individual learning. Inherent aspects that prevail within students prior to engaging in learning, are connected to the behaviour and actions that they adopt. This in turn, affects the outcomes of their learning. A deeper understanding toward the individual dispositions that prevail within design students, are expected to assist teachers to fulfil the distinct learning needs that students have. This thesis addresses a critical factor that is expected to influence students' learning: individual mind-sets in design learning. Mind-sets encompass students' internal mental dispositions and external behavioural responses, that are anticipated to influence the design activities that students engage in, and the quality of design outputs that they produce.

The first part of this thesis, namely Chapters 2 and 3, deals with identifying and assessing the appropriate variables to examine mind-sets that prevail in design learning. The discerning and opportunistic mind-sets were proposed from the first empirical study that is presented in Chapter 3. The second part of the thesis, namely Chapters 4 and 5, dealt with testing the differences between these two mind-sets. Students that incline toward the discerning mind-set were compared to students that incline toward the opportunistic mind-sets. Distinct differences between these two groups in terms of their engagement in the design process and the quality of their design outputs that they produced were found. The different individual dispositions such as their perceived self-efficacy, tolerance for ambiguity, view of own intelligence and preferred learning approaches that characterises these two mind-sets were also examined. Differences found between the two mind-sets provide valuable insights that may help to facilitate design education. Additionally, reflection stimuli to induce deeper *modes of reasoning were introduced to influence the mind-set and test the possibilities of improving the quality of outcomes that students produced. In this last chapter, findings from the three empirical chapters are summarized and presented as contributions for theory building in Section 6. Implications and recommendations for design education are presented in Section 6.2 and the limitations of these studies are discussed in Section 6.3.*

6.1 Contributions of this thesis

The following sections have been divided into five central themes that describe the main findings of this research. The findings contribute to both educational psychology and design cognition literature. RQ1: "Are there prevalent mind-sets that design students have toward design learning and how can they be identified?" is addressed in Sections 6.1.1. RQ2: "What other factors are associated to the adoption of certain types of mind-sets?" is addressed in Section 6.1.2. RQ 3: "Are these mind-sets related to the design processes that students engage in and the outcomes that they produce?" is addressed in Sections 6.1.3 and 6.1.4. RQ 4: "Can interventions be applied to positively influence the performance of design students in design learning?" is addressed in Section 6.1.5. Finally, attributes of the discerning and opportunistic mind-sets that are observed from the three studies are summarized in Section 6.1.6.

6.1.1 RQ 1: Investigating the mind-sets that design students have toward design learning

Mind-sets are assumed to encompass an interplay of internal mental dispositions and external behavioural responses (see Section 2.1). To examine mind-sets, the learning conceptions (the internal aspect of mind-set); and preferred learning approaches and preference for instruction (the external aspect of mind-set) (see Section 2.3.1.3) of design students are investigated. By examining these variables, two distinct mind-sets in design learning are proposed. These two categories of mind-sets are referred to as the *discerning* and *opportunistic* mind-sets.

Students inclining toward a discerning mind-set are found to hold a deep-transforming conception toward learning. This means that they perceive knowledge structures as something to be transformed and require active abstraction and interpretation, in order to acquire meaning (Marton & Säaljö, 1976; Purdie et al., 1996; Van Rossum et al., 1985). They also show preference for instruction and teachers that support the development of their personal understanding. Additionally, they indicated preference to engage in the deep learning approach (see Section 3.3.4 and 0). They engage deeply with design problems that they encounter, seek meaning between concepts, relate ideas and information, and use corroborative evidence to support the development of their design ideas and/or decisions. The discerning mind-set is also uniquely characterised by students' tendencies to discern ambiguity and raise up to challenges that they encounter (see Section 3.3.4). These characteristics which are displayed by design students that incline toward the discerning mind-set, facilitates design learning.

Through the experiential learning theory, learning is defined as a process of grasping and transforming experience to create knowledge (Kolb et al., 2001). In other words, knowledge in designing is gained, by reflecting and experimenting on abstract design concepts, and actively engaging in concrete design experiences i.e., the design activities that a student engages in. Students are recommended to engage in four stages for effective learning: (1) engage in a concrete experience; (2) reflect upon the experience; (3) form abstract concepts and generalizations associated to the experience; and (4) actively experiment with the newly formed understanding by doing (Kolb et al., 2001). The balanced engagement in reflection and experimentation on abstract concepts and concrete experiences, ensures effective learning within students. This theory suggests that students inclining toward the discerning mind-set will be more likely to engage in effective learning i.e., the four stages as suggested by Kolb et al. (2001). The findings in this thesis indicate that they actively reflect on the concepts that they come across in their design courses and exhibit active engagement in their design activities (see Section 3.3.5).

Students inclining toward an opportunistic mind-set on the other hand, are found to be less likely to hold a deep-transforming conception toward learning, not engage in deep learning approaches, and prefer teachers that support the development of their personal understanding. Students inclining toward the opportunistic mind-set are more likely to incline toward teachers that transmit information. Although indirect evidence for the opportunistic mind-set to prefer engaging in the surface learning approach was observed in the first empirical study (see Section 3.3.4), tendencies toward the surface learning approach could be directly observed in the second empirical study (see Section 4.4.1 and 0). This means that some students are indeed more likely to incline toward surface learning approaches that include memorising when presented with information, be bounded to a course syllabus and experience a lack of purpose throughout their education. Additionally, students inclining toward the opportunistic mind-set can uniquely be characterised by their tendencies to take convenient measures. They contrive upon convenient strategies that are easily accessible to them, and will avert undesirable or difficult situations. They also do not delve as deeply into design tasks that they were engaged in. Instead, they engage in design tasks at a surface level, where the connections that they make in design projects are established using non-corroborative evidence (see Section 3.3.7).

The characteristics exhibited by students that incline toward the opportunistic mind-set suggest that they are likely to do well in solving design problems that they are familiar with i.e., where repetitive processes are involved. They will be able to solve these types of problems more rapidly by applying processes that they are accustomed to. Conversely, these findings also suggest that students that incline toward the opportunistic mind-set will engage less actively in the four stages for effective learning as recommended by Kolb et al. (2001), decreasing the possibilities of their effective learning.

Under the assumption that mind-sets within design students can be examined through their learning conceptions, preferred learning approaches and preference for instruction, the discerning and opportunistic mind-sets were proposed. Clear differences between the internal mental dispositions and external behavioural responses of these two mind-sets can be observed, indicating strong evidence for the two categorisations. However, to externally validate these categorisations, other aspects of students' individual dispositions were tested in the different chapters and presented in the following section.

6.1.2 RQ 2: Individual dispositions associated to the adoption of discerning and opportunistic mind-sets

In learning to design, students are expected to interact with unclear, inexplicit and ambiguous problem solving situations. It is thus expected that their perception of self-efficacy, tolerance for ambiguity and view of their own intelligence, may influence the manner in which they manage the complexities in design learning (see Section 2.3.1.4). Students that incline toward the discerning mind-set are expected to perceive these three factors differently than the students that incline toward the opportunistic mind-set. These differences were observed from the second empirical study.

Indeed, students that incline toward the discerning mind-set indicated lower levels of self-efficacy, higher tolerance for ambiguity in problem solving situations and less inclination toward a fixed view of intelligence. Students inclining toward the opportunistic mind-set on the other hand, indicated higher self-efficacy compared to their counterparts, higher tolerance for ambiguity in situations that are related to interpersonal situations and a high inclination toward the fixed view of intelligence (see Section 4.4.1 and 4.4.2). A high agreement toward the fixed view of intelligence means that students view their intelligence and design capabilities as a fixed and unchangeable trait. Conversely, it is likely that this fixed view of one's own intelligence or design capability, is held by design students in many learning situations. For example, individual's that begin to learn drawing usually indicate a common misconception: that they do not naturally have the talent to do so (Edwards, 2012), and as such may be hindered.

The higher levels of self-efficacy, as indicated by students inclining toward the opportunistic mind-set, show that they evaluate their capability to accomplish a task successfully on a higher scale, compared to students that incline toward the discerning mind-set. This indicates that students inclining toward the opportunistic mind-set will be able to regulate their coping behaviours when dealing with complexities associated to design learning that require high reasoning capabilities (Bandura, 1999). However, as they also incline toward the surface and strategic learning approaches (see Section 4.4.1), it is highly likely that they will cope with the complexities that they face by organizing their time and learning activities towards memorizing information and fulfilling course requirements. Christensen et al. (2002) found that when students indicated high levels of their own self-efficacy in the beginning of their semester, their performance was significantly lower compared to students that indicated lower levels of self-efficacy. The authors attributed this circumstance to the over optimism that was exhibited by the students. On the other hand, when students indicated lower levels of self-efficacy, these students achieved better results at the end of the semester. The authors attributed this condition to students' pessimism in their own self-evaluation that led to self-regulatory behaviour which improved their performance in the end. Students inclining toward the discerning mind-set had indicated lower levels of self-efficacy compared to students that inclined toward the opportunistic mind-set. Therefore, it is likely that the discerning mind-set students will engage in self-regulatory behaviour that leads to better outcomes in the end (Christensen et al., 2002). Furthermore, discerning students are associated with the deep-transforming learning conception and deep learning approaches. This additionally supports the notion for possibilities of their reflection and regulatory behaviour that will enable better performance.

Students inclining toward the opportunistic mind-set indicated higher tolerance for ambiguity in situations that are related to interpersonal situations, while students inclining toward the discerning mind-set indicated higher tolerance for ambiguity in problem solving situations (see Section 4.5.1). In a problem solving or design based situation, it is highly likely that tolerance for ambiguous or uncertain situations would impede the seamless course of the project. This is especially so when conditions that need to be clarified are left unattended. This suggests that students inclining toward a discerning mind-set would be more likely to flexibly adapt and better manage within problem solving situations. Additionally, students that incline toward a discerning mind-set would be more likely to avoid ambiguous conditions by clarifying the situation i.e., possibly by facing confrontations during interpersonal communication in order to avoid ambiguity. On the other hand, students inclining toward an opportunistic mind-set would be less analytical in a design or problem solving situation. Additionally, they will be less likely to engage in interpersonal confrontations to communicate any impending ambiguities. If these situations occur, differences in the quality of designs produced by students can be expected based on the mind-set they adopt. Students inclining toward the discerning mind-set are more likely to produce better quality designs.

Students inclining toward the opportunistic mind-set had indicated high levels of self-efficacy and high tolerance for ambiguity in interpersonal related situations. These students also produced lower quality solutions (see Section 4.5.1). In this case, this means that their solutions scored lower in terms of relevance and specificity. On the other hand, students that inclined toward the discerning mind-set indicated lower levels of self-efficacy, and higher tolerance for ambiguity in problem solving situation. These students also produced solutions with higher quality. This finding supports the notion that lower levels of self-efficacy can result in better performance (Christensen et al., 2002), when coupled with self-regulatory behaviour that include conscious contemplation and controlled processing of their learning activities (McLaughlin, 1990). The findings presented show that there are comparable differences between students that incline toward the discerning mind-set, and students that incline toward the opportunistic mind-sets. These differences were interpreted from self-ratings of the design students. In order to validate whether their perceptions align with their actions, additional behavioural data was collected. The meaning of these results is presented in the following section. These results further validate the distinctiveness of the two mind-sets.

6.1.3 RQ 3: Mind-sets in relation to question-asking in designing and outcomes

The behavioural responses of design students that incline toward the discerning and opportunistic mind-sets, are expected to differ from one another. To test whether these differences exist, the questions pertinent to the students regarding the design task that they had to carry out, were examined. The questions that students ask may vary from low level to high level questions (Eris, 2003; Graesser & Person, 1994). It is posited that the sequence of questions that a student asks, when following the proper order and incremental formulation of questions, from low level to high level questions, can yield more reliable forms of knowledge for themselves (Dillon, 1984; Eris, 2002). Distinct differences between the questions that students inclining toward the discerning mind-set asked, can be observed compared to the questions that were asked by students that incline toward the opportunistic mind-set (see Section 4.5.2).

Students inclining toward the discerning mind-set asked more low level questions, while students inclining toward the opportunistic mind-set asked more generative design questions. Low level questions relate to the clarification on missing or incomplete information, while generative design questions refers to questions that lead to the reframing of contexts and concept generation (Eris, 2002). The sequential ordering of questions from low to high and generative design questions enables the establishment of more reliable forms of knowledge (Dillon, 1984; Eris, 2002). However, students that incline toward the opportunistic mind-set engaged in an abrupt or expeditious formulation of question-asking. They jumped to asking generative design questions without formulating lower level questions beforehand. This means that they do not clarify missing or incomplete information related to the design problem, but would immediately generate concepts or solutions for the design problem. This provides further evidence that students inclining toward an opportunistic mind-set, would also incline toward making superficial connections with non-corroborative evidence (Hamat et al., 2015).

Students that incline toward a discerning mind-set, however, did not show these jumps to generative design questions. They engaged in proper incremental question-asking formulations by first trying to understand the design problem through low level questions. In hindsight, the more low level questions students asked, the quality of the solutions that they produced increased. However, no evidence was found to indicate that asking generative design questions related to the increase or decrease in the quality of solutions. This result strongly indicates that the question-asking strategy deployed by students that incline toward the discerning mind-set leads to possibilities of producing design solutions with better quality. It is expected that design students can learn the technique of asking the right questions. Therefore, question-asking techniques can and should somehow be integrated into design learning.

6.1.4 RQ 3: Mind-sets in relation to considerations and design activities

It is really important to know if the attitudes relate to behaviour. Therefore, further validation of whether the self-reported questionnaire items align with the design activities that students engage in was conducted. Two aspects related to design processes are examined. This includes both the considerations that design students take into account and the design activities that they engaged in when designing. To examine the considerations that the design students make, the number of considerations that they made were tallied. The number of specialised topics related to the design task which students considered were also tallied and scored for its level of comprehensiveness (see Section 5.2.2). To examine their design activities, the number of design activities that students engage in during their entire design process were examined. The comprehensiveness of these design activities are also assessed. Comprehensiveness, related to the breadth and depth of the design activities that students immersed themselves in, were subjectively rated by an independent rater (see Section 5.3.5). To examine their design activities, the number of design activities related to the problem and solution space that students engaged in were also assessed.

Differences between the considerations and design activities that students engaged in could be observed between students that incline toward the discerning mind-set, and students that incline toward the opportunistic mind-set.

Students inclining toward a discerning mind-set showed more considerations throughout their design process. They considered more specialised topics related to the design problem and they considered the specialised topics more comprehensively. This is in contrast to students that incline toward an opportunistic mind-set. Students inclining toward a discerning mind-set also engaged in more steps/design activities in their design process. They also engaged in their design activities more comprehensively compared to students that inclined toward an opportunistic mind-set. Further differences can be observed between the discerning and opportunistic mind-sets in terms of the type of design space that they engaged in throughout their design process. Students inclining toward a discerning mind-set engaged in more design activities related to the problem space, compared to students that inclined toward an opportunistic mind-set. In terms of engagement in the solution space however, students inclining toward both mind-sets executed approximately an equivalent number of design activities.

The results strongly indicate that when students incline toward a discerning mind-set, they tend to make more considerations on a deeper level. They will also engage in more design activities more comprehensively. More apparently, these students will spend more time in the problem space prior to generating solutions. These findings of the third study tally with findings from the second study indicating that students inclining toward the discerning mind-set will formulate more low level questions before proceeding to high level and generative design questions (see Section 4.5.2). Students that incline toward the opportunistic mind-set on the other hand, made less considerations, engaged in their design activities less comprehensively and spent less time in the problem space. This resonates with the findings of the first two studies: students that incline toward the opportunistic mind-set tend to expeditiously jump to asking generative design questions, without asking lower and higher level questions beforehand. They also incline toward making superficial connections using non-corroborative evidence (Hamat et al., 2015).

The discerning mind-set is aligned to a balanced use of serialist-holist learning strategies as advocated by Pask (1975). The serialist strategy is to engage in tightly structured step-by-step processes, where students focus on details and evidence, and logically building up their understanding. The holist strategy is to build up understanding by organising and connecting ideas, through a broad overview of topics and also by using of analogies, anecdotes and illustrations. Therefore, the discerning mind-set student may incline toward either the serialist or holist strategies, as both strategies still enables students to develop their understanding (Entwistle, 2001). As previously mentioned, students inclining toward the discerning mind-set engaged in their design considerations comprehensively (depth and breadth), exhibiting similar strategies to that of the serialist-holist learners. On the other hand, students that incline toward the opportunistic mind-set engages in the serialist-holist strategies on a surface level. They engaged less comprehensively in their design activities, and did not go into detail by first asking the low level questions. They jumped into generative design questions, compared to students that inclined toward the discerning mind-set that formulated their questions in sequence, starting with low level questions. Pask refers to these students as "globetrotters", which means that they don't "give sufficient attention to details and tend to generalise and reach conclusions too easily" (as cited in Entwistle, 2001, p. 597). Students' learning can also be adversely affected when they fail to "seek analogies or to use [of their] own experiences [to] make connections with related ideas" (as cited in Entwistle, 2001, p. 597). Similarly, students that incline toward the opportunistic mind-set were found to make connections that were not based on corroborative evidence, when they engaged in their design projects. These students tend to avoid undesirable or difficult situations and implement convenient strategies that are easily accessible to them. For example, they will depend on their teachers to make design decisions for them, rather than reflecting deeply on the task at hand (see Section 3.3.6).

In order to test whether these behaviours and outcomes can be improved, the effects of reflection-oriented stimuli on students that incline toward the discerning and opportunistic mind-sets were examined.

6.1.5 RQ 4: Influence of reflection-oriented stimuli on design solutions

Reflection behaviour is considered important for enabling good design learning, and it is expected that it is possible to induce reflection within design students (Atman & Turns, 2001; Schön, 1983). The manner in which reflection is induced within design students plays a critical role in ensuring students' effectiveness in designing. That is, within the given period of time available for the quasi-experimental studies. The reflection stimuli used in the first experimental study did not yield any significant improvements in terms of outcomes. The stimuli used in the first study consisted of design theories that students had to read, prior to designing. These stimuli required deep internalization and collective sense-making of the theories in order for application in the design process that students engaged in. Due to the short amount of time that was allocated for the design task, immediate and noticeable effects on the quality of solutions that students produced could not be observed.

The stimuli used in the second experimental study, on the other hand, yielded some changes. Changes in terms of students' design processes and quality of outcomes could be observed. In the second experimental study, a more direct way of instigating reflection was used. Questions related to the design problem were included in the design brief for students to reflect and act upon as they deemed necessary. The changes observed are presented in the following sections (see Section 6.1.5.1 and 6.1.5.2).

6.1.5.1 RQ 4: Influence of reflection-oriented stimuli on design process

In terms of the design process that students engaged in, no significant differences could be observed within students that inclined toward the discerning mind-set. There were no significant differences in terms of their design process when they did and did not receive the reflection-oriented stimuli. However, significant differences could be observed within students that inclined toward the opportunistic mind-set.

When students that incline toward the opportunistic mind-set did not receive the reflection-oriented stimuli, they considered a significantly lower number of specialised topics related to the design problem. This is compared to students that incline toward the discerning mind-set that received the stimuli. They also considered the specialised topics less comprehensively and engaged in their design activities less comprehensively, compared to students that incline toward the discerning mind-set and did not receive the stimuli.

When they received the reflection-oriented stimuli, students that incline toward the opportunistic mind-set made significantly more considerations throughout their design process. Conversely, when they received the reflection-oriented stimuli, they still executed a fewer number of design activities, and engaged in these design activities in a less comprehensive manner, compared to students that incline toward the discerning mind-set and did not receive the stimuli. They also executed fewer design activities related to the problem space, compared to students inclining toward the discerning mind-set that received the stimuli.

The results strongly indicate that changes in terms of processes are more possible within students that incline toward the opportunistic mind-set. However, even when the opportunistic mind-set students made significantly more considerations throughout their design process, their considerations and design activities are still comparably lower in count and comprehensiveness compared to students that incline toward the discerning mind-set. This result seems to suggest that the mind-set itself plays a bigger role in facilitating the external behavioural responses that a student exhibits in designing, and that the situations in learning can indeed be changed.

Thus, influencing a change of mind-sets toward a more discerning mind-set seem more reasonable for design students. With regards to the absence of differences within students that incline toward the discerning mind-set, it can be reasoned that these students are already engaged in active reflection throughout their design process. Thus it is less likely to observe any significant differences within these design students.

6.1.5.2 Effect of reflection-oriented stimuli on quality of solutions

Interactions between mind-sets and the quality of design solutions that students produce are expected to be mediated by process or behavioural variables (Armor & Taylor, 2003; Burnette et al., 2013; Zeng, Hou, & Peng, 2016). However, direct relations between mind-sets and the quality of solutions that students produced, could also be observed. When students incline toward a discerning mind-set, they have better chances of coming up with solutions that are communicated with higher clarity, and are more complete and useful, when they do not receive any form of stimuli. This means that their solutions would be communicated better and more easily understood, would more thoroughly solve the design problem, and would considerably benefit the stakeholders involved in the design problem. However, no significant differences in the quality of solutions could be observed between the discerning and opportunistic mind-set students when they were asked additional questions at the bottom of the design brief as their experimental treatment.

When students incline toward the opportunistic mind-set, and did not receive the stimuli, they produced solutions that were more feasible i.e., were less complicated or difficult to implement, compared to opportunistic mind-set students that received the stimuli, and discerning mind-set students that did not receive the stimuli. In other words, the solutions produced by opportunistic mind-set students that did not receive the stimuli did not differ much from the existing conditions within the design problem, as their solutions would not require drastic modifications from the existing facilities, or complicated requisitions in terms of manufacturing and technological advances.

These results indicate that the reflection-oriented stimuli had a positive effect in students that incline toward the opportunistic mind-set. When they received the stimuli, their solutions changed more drastically compared to the existing conditions within the design problem. However, the reflection-oriented stimuli did not have any influence on solutions that were produced by students that incline toward the discerning mind-set. Instead, the design students that incline toward the discerning mind-set produced better solutions when they did not receive the reflection-oriented stimuli. This indicates that when students that incline toward the discerning mind-set are exposed to additional reflection stimuli, adverse effects might occur. Instead, different methods of stimulation can be examined. As discussed in Section 6.1.1, a possible stimuli to adopt is the simulation of the four stages for effective learning as advocated by Kolb et al. (2001). Students can be led to engage in the four stages for effective learning. This includes to firstly engage in a concrete experience, then reflect upon the experience, and then to form abstract concepts and generalizations associated to the experience, and finally to actively experiment with the newly formed understanding by doing. An example of such an attempt was conducted by TU Delft in the massive open online course that they offered (Daalhuizen & Schoormans, n.d.). Specific materials and teaching aids should however be tailor-designed for the experimental or teaching purposes.

6.1.6 Attributes of the discerning and opportunistic mind-sets

The three studies have revealed distinctive differences between the discerning and opportunistic mind-sets on the three levels of Bigg's 3P model (see Section 2.3). On the presage level, the learning approaches, learning conceptions, preference for instruction, perception of self-efficacy, tolerance of ambiguity and view of own intelligence of design students were assessed. On the process level, the types of questions that students ask and the considerations that they made throughout their design process were assessed. On the product level, the quality of solutions that students produced were assessed.

It can be concluded that students inclining toward the discerning mind-set show controlled processing of their learning activities. This is in contrast to students that incline toward the opportunistic mind-set. For a detailed overview of the differences on the three levels of the 3P model, see Table 6.1. The attributes of the discerning and opportunistic mind-sets from the three studies are summarized.

6.2 Implications and recommendations for design education

Identification of the two distinctive mind-sets and their characteristic traits in design learning and designing, provide potential implications for design education. Recommendations for administrators that are responsible for managing design education in general, teachers of design courses and students of design are put forward.

Findings strongly suggest that potential design students that incline toward the discerning mind-set are more readily prepared for the complexities of design learning. In comparison, potential students that incline toward an opportunistic mind-set might require supplementary attention and didactics or instruction in order to flourish in their design learning. For the educational body, educating students that incline toward an opportunistic mind-set involve a surplus of operational expenditures which encompass human and economical capital. To ensure the success of a design school, this involves the development of proper course syllabuses that enable the development of discerning mind-sets within all students. It also involves investment in terms of teacher training and expertise, to fulfil the needs of students with opportunistic mind-sets.

Table 6.1 Overview of attributes for the discerning and opportunistic mind-sets

Attributes	Opportunistic Mind-set	Discerning Mind-set
Presage level		
Learning approach (LA)	Surface LA	Deep and Strategic LA
Learning conception (LC)	Low deep-transforming LC	High deep-transforming LC
Preference for instruction	Lower preference for instruction that that supports understanding	Higher preference for instruction that supports understanding
Perception of self-efficacy	High	Low
Tolerance for ambiguity	High in problem solving situations	High in interpersonal related situations
View of own intelligence	Higher fixed view	Lower fixed view
Process level		
Question-asking strategy	Sequential	Not sequential
Considerations throughout design process	Less comprehensive	More comprehensive
Product level		
Quality of solutions	Lower clarity, completeness and usefulness	Higher clarity, completeness and usefulness
Response to reflection-oriented stimuli:		
In terms of outcomes	Better quality solutions	No observable effect
In terms of process	Considerations become more comprehensive, but still less comprehensive compared to the discerning mind-set	No observable effect
Other characteristics	Takes convenient measures, makes superficial connections	Rises up to challenges, engages in active reflection and exploration

In current design education, however, teachers are presently faced with the challenge of educating design students that incline toward both mind-sets. Students that incline toward the opportunistic mind-set are more likely to encounter difficulties throughout their design education. Nevertheless, when these students were given the reflection – oriented stimuli compelling evidence that the behaviour and outcomes that they produced can be improved. This strongly suggests that students that incline toward an opportunistic mind-set need stimulation in terms of presage level factors i.e., to make the students more reflective and discerning (see conceptual model of this thesis in Section 2.3). These factors are related to individual dispositions within the students themselves that exist prior to their actual learning. It is thus important that teachers are aware of the specific stimulation that these students require in their design learning, and invest their time and attention to engage students toward a more discerning mind-set.

The development of resources in order to improve students' mind-sets, which more importantly, enable their independence in reflective and critical thinking, should thus be fostered. These resources might be embedded into competence monitors that are currently used in universities to keep track of students' progress.

Findings also suggest that students should be motivated and taught ways of managing and harnessing the benefits of their individual dispositions. For example, they should be motivated to view their own intelligence and capabilities as a developable trait, as opposed to a fixed trait that cannot be changed. They should also be made aware of the ambiguity in solving design problems and be trained to manage ambiguous situations. Furthermore, design students should also be taught about the types and strategies of formulating questions. Questions that are better structured can establish more reliable forms of knowledge, and enable students to better understand the design problems they engage in, enabling them to formulate positive imminent behaviours and actions. The development of discerning mind-sets however, also needs to be fostered by the students themselves. Design students should be more aware of their individual dispositions that exist prior to engagement in learning as these factors influence the way they engage in learning and the outcomes of their learning. Students should also be aware of their own levels of self-efficacy so that they can regulate their own learning activities. Whether they are optimistic or pessimistic of their own prior performance, they should be aware of these conditions and be able to manage these situations. Ultimately, better design learning is more likely to occur when design students are more mindful of their own personal tendencies, and actively harness their individual capabilities.

6.3 Limitations and recommendations for future studies

The limitations and recommendations for future studies that can be derived from this thesis are as follows:

In Chapters 2 and 3, variables related to learning conceptions, learning approaches and preference for instruction were selected to examine the internal and external components of mind-sets in design learning. These variables were expected to provide insights related to the internal mental dispositions and external behavioural responses that determine an individual's reaction or approach to design learning in general. However, these variables are postulated by the author and do not fully represent personal constructs from the design student themselves. Future studies should take this aspect into account and focus on the perspective of the design students themselves. In hindsight, a constructivist approach will enable the exploration and build-up of understanding from the design students' own internal perspective. One such method propagated within the constructivist approach includes the use of repertory grids (Burr et al., 2012). This method allows for students to provide descriptions by exploring contrasting poles of a construct, from their own perspective, in relation to their mind-sets within design learning (Denicolo et al., 2016). This method offers a much more flexible yet structured cluster of variables to be examined. Furthermore, it works upon constructs that are derived from the design students themselves, as opposed to stemming from the researcher.

In Chapters 4 and 5, data for the empirical studies were obtained from controlled experimental conditions, thus there are limitations to generalising these results to the actual design studio setting. Other variables that possibly exist in the real learning situation are not fully captured. Thus, only inferences to the actual learning situation can be made. However, the experiments were made in studio rooms that the students were familiar with, which controls for unanticipated classroom/studio environment related variables.

Data were also gathered only at a single point in time for both these studies, resulting in the absence of process data. Thus, students' adoption of learning approaches throughout or at specific points of the complex design process could not be captured. Future studies should then take into consideration the possibility of longitudinal studies to measure differences within individuals or isolate distinctly different parts of the design process. This would enable comparisons between the different phases to obtain a clearer delineation of students' design learning. In addition, the stimuli used within the second empirical study, did not yield any observable differences within the students (see Section 4.3.2). It is assumed that limitations in terms of time and complexity of the stimuli, restricted the possibilities of observing any changes.

In an experimental context, it is expected that these limitations can be overcome by streamlining the instrument of stimulation, and by increasing the amount of time given, for students to engage with the instrument and the design problem. In an actual design learning setting however, it is expected that improvements within these students can be more readily observed. This is because the amount of time that students will have shall allow for much more active engagement with the content knowledge that the education system provides for them. Hence, more time might be needed for future attempts in integrating this type of stimuli in future studies or possibly, in actual design learning situations.

In the third empirical study, the stimuli given to the participants yielded differences only within students that inclined toward the opportunistic mind-set. This strongly indicates that students that incline toward the discerning mind-set require different stimulation in their design learning. Evidence for the type of stimulation that discerning mind-set students require, were however not uncovered within the studies of this thesis. In hindsight it is probable that these students require stimulation of a different nature, compared to that required by students that incline toward the opportunistic mind-set. It could also possibly be due to a ceiling effect, where students that inclined toward the discerning mind-set were already performing at a good level. Conversely, depending on the context of the design problem, suitable creativity methods or design methods can be introduced to examine whether the performance of design students that incline toward the discerning and opportunistic mind-sets can be increased. Comparisons between creative methods such as personas, analogies and mind-mapping with structured and rational methods such as TRIZ, ViP (van Dijk & Hekkert, 2014) and functional analysis should also be attempted. In retrospect, these comparisons can possibly provide insights on how to optimize the individual dispositions related to the two mind-sets. That is, whether the discerning and opportunistic mind-set students would prefer and perform better using systematic or heuristic methods.

Data were mainly collected from a sample of design students in Malaysia. Although this thesis focusses particularly on data samples collected from these students, the differences that emerged from these empirical studies are expected to apply to design education more broadly, as the background of learning and the structure of the design programmes that design students enrol in are comparable. It can be reasoned that the generalisability of the findings still holds, as it is anticipated that these results can be collectively attributed to design students from similar backgrounds or training. These students are exposed to same educational programmes i.e., from maths, science, geography, history and physics, to design methods, sketching classes and materials engineering. Furthermore, in this era of globalisation, it can be expected that these students will be listening to the same types of mainstream music, watching the same yearly MTV Music awards and Netflix movies, and even playing the same Grand Theft Auto or Warcraft games. As people begin to eat the same food, listen to the same music and enjoy the same entertainment, it can be expected that it is the individual differences between people that stand out for examination. However, future studies should also include samples of students from varying design courses and cultural backgrounds, to validate and increase the generalisability of the findings.

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Appendices

Appendix A: ASSIST Questionnaire

Approaches and Study Skills Inventory for Students (ASSIST)

This questionnaire has been designed to allow you to describe, in a systematic way, how you go about learning and studying. The technique involves asking you a substantial number of questions which overlap to some extent to provide overall coverage of different ways of studying. Most of the items are based on comments made by other students. Please respond truthfully, so that your answers will **accurately** describe your **actual** ways of studying, and work through the questionnaire quite **quickly**.

Background Information

University: ______________________

Course: ______________________

Faculty: ______________________

Age: ______________________

Sex: M/F

Year of study: ______________________

Prior education, please state: ______________________

A. What is learning?

When you think of the term 'LEARNING', what does it mean to you?
Consider each of these statements carefully, and rate them in terms of how close they are to **your own** way of thinking about it.

	Very different	Rather different	Not so close	Quite close	Very close
a. Making sure you remember things well.	1	2	3	4	5
b. Developing as a person.	1	2	3	4	5
c. Building up knowledge by acquiring facts and information.	1	2	3	4	5
d. Being able to use the information you've acquired.	1	2	3	4	5
e. Understanding new material for yourself.	1	2	3	4	5
f. Seeing things in a different and more meaningful way.	1	2	3	4	5

Please turn over

B. Approaches to studying

The next part of this questionnaire asks you to indicate your relative agreement or disagreement \ comments about studying made by other students. Please work through the comments, giving \ **immediate** response. In deciding your answers, think in terms of **this particular design programme.** It is very important that you answer **all** the questions: check that you have.

1= disagree **(x)** 2=disagree somewhat **(x?)** 3=unsure **(??)** 4=agree somewhat **(/?)** 5=agree

Try __not__ to use 3=Unsure, unless you really have to, or if it cannot apply to you or your course.

	(x)	(x?)	(??)	(/?)
1. I manage to find conditions for studying which allow me to get on with my work easily.	1	2	3	4
2. When working on an assignment, I'm keeping in my mind how best to impress the marker.	1	2	3	4
3. Often I find myself wondering whether the work I am doing here is really worthwhile.	1	2	3	4
4. I usually set out to understand for myself the meaning of what we have to learn.	1	2	3	4
5. I organise my study time carefully to make the best use of it.	1	2	3	4
6. I find I have to concentrate on just memorising a good deal of what I have to learn.	1	2	3	4
7. I go over the work I've done carefully to check the reasoning and that it makes sense.	1	2	3	4
8. Often I feel I'm drowning in the sheer amount of material we're having to cope with.	1	2	3	4
9. I look at the evidence carefully and try to reach my own conclusion about what I'm studying.	1	2	3	4
10. It's important for me to feel that I'm doing as well as I really can on the courses here.	1	2	3	4
11. I try to relate ideas I come across to those in other topics or other courses whenever possible.	1	2	3	4
12. I tend to read very little beyond what is actually required to pass.	1	2	3	4
13 Regularly I find myself thinking about ideas from lectures when I'm doing other things.	1	2	3	4
14. I think I'm quite systematic and organised when it comes to revising for exams.	1	2	3	4

15.	I look carefully at tutors' comments on course work to see how to get higher marks next time.	1	2	3	4	5
16.	There's not much of the work here that I find interesting or relevant.	1	2	3	4	5
17.	When I read an article or book, I try to find out for myself exactly what the author means.	1	2	3	4	5
18.	I'm pretty good at getting down to work whenever I need to.	1	2	3	4	5
19.	Much of what I'm studying makes little sense: it's like unrelated bits and pieces.	1	2	3	4	5
20.	I think about what I want to get out of this course to keep my studying well focused.	1	2	3	4	5
21.	When I'm working on a new topic, I try to see in my own mind how all the ideas fit together.	1	2	3	4	5
22.	I often worry about whether I'll ever be able to cope with the work properly.	1	2	3	4	5
23.	Often I find myself questioning things I hear in lectures or read in books.	1	2	3	4	5
24.	I feel that I'm getting on well, and this helps me put more effort into the work.	1	2	3	4	5
25.	I concentrate on learning just those bits of information I have to know to pass.	1	2	3	4	5
26.	I find that studying academic topics can be quite exciting at times.	1	2	3	4	5
27.	I'm good at following up some of the reading suggested by lecturers or tutors.	1	2	3	4	5
28.	I keep in mind who is going to mark an assignment and what they're likely to be looking for.	1	2	3	4	5
29.	When I look back, I sometimes wonder why I ever decided to come here.	1	2	3	4	5
30.	When I am reading, I stop from time to time to reflect on what I am trying to learn from it.	1	2	3	4	5
31.	I work steadily through the term or semester, rather than leave it all until the last minute.	1	2	3	4	5
32.	I'm not really sure what's important in lectures so I try to get down all I can.	1	2	3	4	5
33.	Ideas in course books or articles often set me off on long chains of thought of my own.	1	2	3	4	5
34.	Before starting work on an assignment or exam question, I think first how best to tackle it.	1	2	3	4	5
35.	I often seem to panic if I get behind with my work.	1	2	3	4	5
36.	When I read, I examine the details carefully to see how they fit in with what's being said.	1	2	3	4	5
37.	I put a lot of effort into studying because I'm determined to do well.	1	2	3	4	5
38.	I gear my studying closely to just what seems to be required for assignments and exams.	1	2	3	4	5
39.	Some of the ideas I come across on the course I find really gripping.	1	2	3	4	5
40.	I usually plan out my week's work in advance, either on paper or in my head.	1	2	3	4	5
41.	I keep an eye open for what lecturers seem to think is important and concentrate on that.	1	2	3	4	5
42.	I'm not really interested in this course, but I have to take it for other reasons.	1	2	3	4	5
43.	Before tackling a problem or assignment, I first try to work out what lies behind it.	1	2	3	4	5
44.	I generally make good use of my time during the day.	1	2	3	4	5
45.	I often have trouble in making sense of the things I have to remember.	1	2	3	4	5
46.	I like to play around with ideas of my own even if they don't get me very far.	1	2	3	4	5
47.	When I finish a piece of work, I check it through to see if it really meets the requirements.	1	2	3	4	5
48.	Often I lie awake worrying about work I think I won't be able to do.	1	2	3	4	5
49.	It's important for me to be able to follow the argument, or to see the reason behind things.	1	2	3	4	5
50.	I don't find it at all difficult to motivate myself.	1	2	3	4	5
51.	I like to be told precisely what to do in essays or other assignments.	1	2	3	4	5
52.	I sometimes get 'hooked' on academic topics and feel I would like to keep on studying them.	1	2	3	4	5

C. Preferences for different types of course and teaching

1= definitely dislike **(x)** 2=dislike to some extent **(x?)** 3=unsure **(??)** 4=like to some extent (/?) 5=definitely like **(/)**

Try <u>not</u> to use 3=Unsure, unless you really have to, or if it cannot apply to you or your course.

		(x)	(x?)	(??)	(/?)	(/)
a.	Lecturers who tell us exactly what to put down in our notes.	1	2	3	4	5
b.	Lecturers who encourage us to think for ourselves and show us how they themselves think	1	2	3	4	5
c.	Exams which allow me to show that I've thought about the course material for myself.	1	2	3	4	5
d.	Exams or tests which need only the material provided in our lecture notes.	1	2	3	4	5
e.	Courses in which it's made very clear just which books we have to read.	1	2	3	4	5
f.	Courses where we're encouraged to read around the subject a lot for ourselves.	1	2	3	4	5
g.	Books which challenge you and provide explanations which go beyond the lectures.	1	2	3	4	5
h.	Books which give you definite facts and information which can easily be learned.	1	2	3	4	5

Finally, how well do you think you have been doing in your assessed work overall, so far?
*Please rate yourself **objectively**, based on the grades you have been obtaining*

Very Well		Quite Well		About Average		Not So Well		Rather Badly
9	8	7	6	5	4	3	2	1

Thank you very much for spending time completing this questionnaire: it is much appreciated

Appendix B Reliability of scales

Scale	Cronbach's Alpha	Original number of items	Final number of items
Learning approach			
Deep	0.78	28	15
Strategic	0.79	8	8
Surface	0.78	16	13
Learning conception			
Surface -Reproducing	0.43	3	3
Deep -Transforming	0.60	3	3
Preference for instruction			
Transmitting information	0.59	4	4
Supporting understanding	0.48	4	4

Appendix C: INTERVIEW GUIDELINE

Student interview guide

The purpose of this interview is to identify types of mindsets students have towards their learning in industrial design courses. Students' perception of what they learn, how they learn, why they learn and how they want to learn will be investigated. The flow of the interview will be divided into two main parts starting from the student's ***present learning experience*** (students will either be in their first year second semester or final year), going backwards to enable the students to recall their ***initial first year learning experience***.

First Name:	Matrix/STPM/Diploma
Gender:	Year/Course:
Race:	University/ Faculty:

Interview Notes:

*Use **illustrative examples** if interviewee seems to struggle to facilitate deeper response only after initial questions fails to elicit thoughtful response.

*add **"if any"** to make more neutral framing

***probing questions**: use who, where, what, when, how to obtain complete and detailed picture of activity or experience

***Preface statements** to introduce question

Introduction:

Hello, I'm Basyarah Hamat and I'm doing research on how students in design courses learn. You are the expert in this area and I would like to learn about the experiences that you've gone through as a design student, so I will ask you some questions on that. This interview will consist of two parts. The first part will be about your present learning experience and the second part will be about your transition to the university environment.

Please know that this interview has no influence what so ever towards the marking of any of your design projects and anything you say will be kept confidential and be strictly kept anonymous. Please feel free to give your opinion on the questions asked.

Hello, saya Basyarah Hamat dan saya sedang membuat kajian mengenai bagaimana pelajar dalam kursus design belajar. Kamulah pakar dalam hal ini jadi saya perlu bertanyakan kepada kamu mengenai pengalaman yang telah kamu lalui sebagai seorang pelajar rekabentuk. Soalan akan terbahagi kepada dua bahagian. Bahagian yang pertama merangkumi soalan mengenai pengalaman pembelajaran kamu pada masa ini (present) dan bahagian yang kedua adalah sewaktu peralihan kamu ke university.

Temuramah ini langsung tidak mempengaruhi markah kamu dalam kursus ini dan apa jua yang kamu nyatakan di sini adalah dianggap sebagai data yang sulit. Adakah adik setuju untuk ditemuramah?

Part 1: Present learning experience (1st year second semester/Final year)

Bahagian pertama:Pengalaman belajar pada waktu ini

Questions	Notes
Warm up questions: What is your first name? ***Boleh saya tahu, apa nama kamu?*** In what year are you studying? ***Kamu sedang belajar dalam tahun berapa?*** Where are you from? ***Asal dari mana?*** How do you like studying in this program? ***Bagaimanakah kamu menyukai program yang sedang kamu ambil ini?***	

Perception of learning: currently in university studies
 	
What courses are you taking besides design courses this semester?
Apakah kursus yang kamu ambil untuk semester ini?
What do you think about those?
Apa pendapat kamu mengenai kursus-kursus yang kamu ambil ini?
 	
Do they have lectures, tutorials, labs, or non-design related projects?
Adakah kursus-kursus tersebut mempunyai kuliah, tutorial, lab atau projek yang tidak melibatkan rekabentuk?
 	
Lectures/ Tutorials/Labs /Non-design related projects
• Do you attend lectures?
• ***Adakah kamu menghadiri kuliah?***
• Why, or why not?
• ***Mengapa kamu menghadiri/ tidak menghadiri kuliah?***
• What is a good lecture?
• ***Pada pendapat kamu, apakah kuliah yang baik?***
• What do you do to understand the content of lectures better?
• ***Apa yang akan kamu lakukan untuk memahami kandungan kuliah dengan lebih baik?***
Probes:
  ◦ What do you do before lectures?
  ◦ ***Lazimnya, apa yang akan kamu lakukan sebelum kuliah?***
  ◦ What do you do during lectures?
  ◦ ***Lazimnya, apa yang kamu lakukan sewaktu kuliah?***
  ◦ How do you take notes during lectures?
  ◦ ***Bagaimanakah kamu mengambil nota sewaktu kuliah?***
  ◦ What do you do after lectures?
  ◦ ***Lazimnya, apa yang akan kamu lakukan sesudah kuliah?***
• Do you think you can do anything differently compared to what you're doing now to make yourself understand the content of the lectures better?
• ***Pada pendapat kamu, adakah kamu boleh melakukan sesuatu yang berbeza berbanding apa yang lazimnya kamu lakukan sekarang untk membuat kamu memahami kandungan kuliah dengan lebih baik?***
	*Use **illustrative examples** if interviewee seems to struggle to facilitate deeper response only after initial questions fails to elicit thoughtful response.
	
	***Follow up with same questions for tutorials, labs and non-design related projects**

Questions	Notes
Design studio experiences	

Do you attend studio-based design classes?
Adakah kamu menghadiri kelas studio rekabentuk?

Why, or why not?
Mengapa kamu menghadiri/tidak menghadiri kelas studio rekabentuk?

What is a good studio-based design class?
Pada pendapat kamu, apakah kelas studio rekabentuk yang baik?

What do you do to understand the content of studio-based design classes better?
Apa yang akan kamu lakukan untuk memahami kandungan kelas studio rekabentuk dengan lebih baik?

What are you learning in studio-based design classes?
Apa yang kamu belajar dalam kelas studio rekabentuk?

What do you think about the studio-based design classes you are currently taking?
APakah pendapat kamu mengenai kelas studio rekabentuk yang sedang kamu lalui?

What motivates you to attend studio-based design classes?
Apakah yang menjadi motivasi kamu untuk menghadirkan diri ke kelas studio rekabentuk?

Process/ Proses

- What do you do before studio-based design classes?
- ***Lazimnya, apa yang akan kamu lakukan sebelum kelas studio rekabentuk?***
- What do you do during studio-based design classes?
- ***Lazimnya, apa yang kamu lakukan sewaktu kelas studio rekabentuk?***
- How do you take notes during studio-based design classes?
  Bagaimanakah kamu mengambil nota sewaktu kelas studio rekabentuk?
- What do you do after studio-based design classes?
  Lazimnya, apa yang akan kamu lakukan sesudah kelas studio rekabentuk?
- How are the projects introduced to you by the lecturers?
  Bagaimanakah pensyarah kamu memperkenalkan sesuatu projek kepada kamu?
- What do you do after they are introduced?
  Lazimnya, apakah yang akan kamu lakukan setelah ia diperknalkan kepada kamu?
- What do you do to make yourself understand the requirements of the project?
  Apa yang kamu lakukan untuk memahami kehendak sesuatu projek?
- How do you go about doing the projects?
  Lazimnya, bagaimanakah kamu menjalankan projek-projek tersebut?
- Have you had any experiences that were particularly difficult when executing the projects?
  Adakah kamu pernah mengalami kesusahan sewaktu mejankan projek-projek tersebut?

Content/Kandungan

- What are you learning in this semester's design studio?
  Apa yang sedang kamu pelajari dalam kelas studio rekabentuk semester ini?
- What was the last project that you did?
  Apakah projek terakhir yang telah kamu lakukan?
- What did you learn from that project?
  Apakah yang kamu pelajari dari projek tersebut?
- Have you had any experiences during the design studio course that you think was really important?
  Adakah kamu melalui pengalaman yang kamu rasa adalah amat penting sewaktu kelas studio rekabentuk?
- How do you relate the different subjects that you've taken simultaneously with design courses to the projects that you're doing? Could you give an example of how you did it?
  Bagaimanakah kamu mengaitkan subjek lain yang diambil seiring kelas studio rekabentuk dengan projek yang kamu jalankan? Boleh kamu berikan contoh bagaimana kamu lakukannya?

Capability

- What capabilities have you developed so far in the design studio courses you have taken?
  Apakah kebolehan yang telah kamu perolehi sepanjang kelas studio rekabentukyang telah kamu lalui?
- What capabilities do you think you should have developed?
  Pada pendapat kamu, apakah kebolehan yang sepatutnya kamu perolehi?

Instructors/

- How do the instructors teach in the design studio?
  Bagaimanakah pensyarah kamu mengajar di dalam kelas studio rekabentuk?
- Were there any theories, concepts or paradigms that the instructors introduced to you in the design studio?
  Adakah pensyarah kamu memperkenalkan sebarang teori, konsep atau paradigm di dalam kelas studio rekabentuk?
- What do the instructor's put emphasis on in the design studio?
  Apakah penekanan yang diberikan oleh pensyarah kamu dalam kelas studio rekabentuk?
- What would you prefer the instructor's to do in the design studio classes?
  Apakah yang kamu mahu pensyarah kamu lakukan di dalam kelas studio rekabentuk?

Part 2: Transition to the university environment

Questions	Notes
Perception of learning: transition to university	

Now, for the second part of the interview, it will be about your initial learning experience when you first entered the university.
Sekarang, soalan adalah mengenai pengalaman belajar kamu sewaktu kamu mula-mula masuk ke university dahulu.

Pre-University Experience

- Where did you study before entering the university?
  Dimanakah kamu belajar sebelum memasuki univesiti?
- What did you study there?
  Apakah yang telah kamu pelajari di sana?
- What did you know about this program when you first came into the university?
  Apakah yang kamu tahu mengenai program ini sewaktu kamu mula-mula memasuki university ini?

Content

- When you first entered the university, if any at all, what did you expect to learn in this design program?
  Sewaktu mula-mula memasuki univesiti ini, jika ada, apakah yang kamu jangkakan akan kamu pelajari daripada kursus rekabentuk ini?
- If you recall back to when you studied before you, was there anything different about what you learned in this design program compared to what you studied before?
  Jika diingat kembali, sewaktu kamu belajar dahulu, adakah terdapat apa-apa perbezaan mengenai apa yang dipelajari dahulu dibandingkan dengan apa yang kamu pelajari dalam kursus rekabentuk ini?
- When receiving new content from the lecturers, what did you do with the new information?
  Sewaktu kamu menerima apa-apa bentuk pengetahuan baru daripada pensyarah kamu, apa yang kamu lakukan dengan pengetahuan baru itu?

Process

- Are there any differences between how classes were conducted in high school with how they are conducted in the university?
  Adakah terdapat apa-apa perbezaan antara bagaimana kelas dijalankan berbanding di universiti dan sebelum kamu memasuki university?
- If you were to compare between how you were studying before entering university compared to how you are studying after, what do you think has changed?
  Jika dibandingkan mengenai bagaimana kamu belajar sebelum memasuki university dengan bagaimana kamu belajar sekarang, pada pendapat kamu, apakah yang telah berubah?
- How did you adapt to studying here?
  Bagaimanakah kamu adaptasikan diri untuk belajar di sini?

Capability

- When you first started this program, what kinds of ***capability***, if any, did you think would be required for this program?
  Sewaktu baru memulakan program ini, apakah jenis kebolehan diri, jika ada, yang pada pendapat kamu diperlukan untuk program ini?
- Did you have those capabilities when you entered? If not, how did you develop them?
  Adakah kamu mempunyai kebolehan tersebut sewaktu kamu memasuki universiti ini? Jika tidak, bagaimanakah kamu mengasah kebolehan tersebut?

Instructors

- When you first started this program, how were you expecting the instructors to teach in lectures, studios, tutorials and labs?
  Sewaktu baru memulakan programini, bagaimanakah kamu menjangkakan para pensyarah mengajar di dalam kuliah, tutorial, lab dan kelas studio rekabentuk?
- When you first started this program, were you comfortable with how they taught you in studio classes?
  Sewaktu memulakan program ini dahulu, adakah kamu merasa selesa dengan kaedah pengajaran pensyarah kamu di dalam kelas studio rekabentuk?
- When you first started this program, what did you think of the approaches that the lecturers use in design studios?
  Sewaktu memulakan program ini dahulu, apakah pendapt kamu mengenai kaedah pengajaran pensyarah kamu di dalam kelas studio rekabentuk?

Is there anything else related to:
Adakah terdapat perkara lain yang berkait:

- Your experience like when you first came into the university?
  Dengan pengalaman kamu sewaktu mula-mula memasuki university?
- Your expectations of the learning environment when you first came into this university?
  Jangkaan kamu mengenai suasana pembelajaran kamu sewaktu mula-mula memasuki university ini?

Is there anything else that you would like to add, just in case if you feel I have missed any aspects that you feel would be important to add?
Adakah terdapat apa-apa aspek yang kamu rasa penting dan hendak kamu tambah?
Thank you very much for your time. It is greatly appreciated.

Appendix D: Pattern codes created in second cycle

Code		Definition	Example of quotation
Learning Approach			
Deep			
1.	*Faces challenges*	Overcoming or rising up to the task when faced with challenging situations.	*"I will... like try and error... Try out everything possible. And then try to see whether it will... look nice in this position, this arrangement, if it's not, then I will try it in another arrangement. Because this... we need to try it on our own."* ***(Respondent ID:1)***
2.	*Interest in ideas*	Actions that indicate interest towards content or procedural knowledge.	*"...then actually, I am also interested in how to study visuals... like in critique sessions, there was one project, I was thinking... how he should research about the visual... if it is true that "iconic" and kuala lumpur is related, then how he will transfer it into the design of the taxi... with iconic, what is iconic actually...?"* ***(Respondent ID: 5)***
3.	*Relating ideas*	Actions to relate content or procedural knowledge.	*"What I jot down is... I had already concluded it... the scope of his project was very big... like it can be classified as 2 projects, because he is study about "iconic", kl and also the taxi... 3 things! but 3 things are interconnected... and then, erm... there is kl and iconic, iconic and taxi..."* ***(Respondent ID: 5)***
4.	*Seeking meaning*	Attempts to fathom concepts.	*"For example, in the product design class, I would find out the functions of every part on the circuit board. Because before this I didn't know about it. I find out how each part functions...."* ***(Respondent ID: 12)***
5.	*Using evidence*	Demonstrates decisions made based on deliberation.	*" Before fabricating the prototype, to identify any possible mistakes, I would make a mock-up first... This is so I can physically look at the proportion of the form, otherwise, it will just be on paper..."* ***(Respondent ID: 4)***

Strategic			
6.	*Alert to assessment demands*	Actions perceived as an enabler to attain higher marks.	*"Emm... because if it is related to my project... if I think it's important... ya... when he says that there are more marks for this... or something like that... because our projects are relate to our thesis... so if he says that it is important, I would take note on that..."* ***(Respondent ID: 6)***
7.	*Monitors effectiveness*	Actions to examine or prepare content of work or assignments.	*"... Usually, after class, I will look back at what was not enough and add to it... if I'm not satisfied with the work, I will usually add whichever is not enough. If I want to add more research... or anything to my designs or something like that... I would do it beforehand..."* ***(Respondent ID: 10)***
8.	*Organised studying*	Actions to enable accomplishment of work through systematic organisation or time planning.	*"Assignments for design class...? I would usually do it in classes, not waste time... because if I wanted to do it back at my hostel... there would not be enough time... so... do it until its done... If possible, it has to be finished quickly... because if the lecturer asks for it and I had to do it in the last minutes, it would be tiring... so just do the work... I have to be disciplined..."* ***(Respondent ID: 2)***
Surface			
9.	*Taking convenient measures*	Actions taken to decrease work load that compromises deeper levels of processing.	*" ...I was doing the research on the tree....so if I changed the subject matter, I would have to conduct all of my research all over again... so I changed to [looking at] its fruit, I didn't take the branch [anymore]... I used the branch for the lighting project and the fruit for the furniture project... so I don't have too much research that I needed to do as I had already researched about the tree..."* ***(Respondent ID: 10)***
10.	*Limited use of evidence*	Utilization of only accessible information without considering imperative requirements as required by task/situation.	*" ...I would think of my own logics, what I am fond of... I pick the living room for the family so that my own family can use it later on... besides, compared to the toilet and kitchen, users don't use the space as frequently as they do the living rooms... so there is more opportunity for me to research for problems... "* ***(Respondent ID: 11)***

11. *Performs routine actions*	Execution of customary actions that includes memorising, executing instructions or actions with limited understanding.	*" ...we will need to complete last week's assignments... for example, if the lecturer asks to make thumbnails or development, so we will do a little bit of development... so before the class, we will prepare the development that we've done... so during class, show it to the lecturer and get approval to proceed... "* ***(Respondent ID: 12)***

Preference for instruction	Definition	Example of quotation
Supports understanding		
12. *Conveys ideas coherently*	Students clearly understand ideas that are conveyed by their instructors.	*"...then I learnt a lot from the critique sessions, when we discussed about my friend's project... although our projects are different, but I learn from everybody's project... there are more examples... like its easier to understand what the design process is about... overall..."* ***(Respondent ID: 5)***
13. *Monitors understanding*	Lecturer checks whether students understand.	*"...each time before giving us the assignment, the lecturer will ask whether we understand how to go about... if we're all quiet, it means that it's the first time we've heard about it... so, when the lecturer knows that it's new for us, he will explain how we should do it..."* ***(Respondent ID: 11)***
14. *Promotes reflection*	Lecturer propagates reflection through questioning or encouraging exploration.	*"...for example, when I present my project, the lecturer questioned, what did I mean by small, medium or large... for the event... and what programmes were they doing on the stage... ? I didn't look into that aspect... that was one thing that helped... the lecturer suggested to look at this ,this ,this...* ***(Respondent ID: 4)***

Transmit information			
15.	*Dictating design direction*	Decision making process is made by instructors.	*"...the lecturer will explain what we need to do, then we will conduct our research... once the research is complete, we will present it to the lecturer... depending on whether the lecturer likes it or not, we will design it... if the lecturer accepts everything, right... we will proceed to make the thing..."* ***(Respondent ID: 9)***
16.	*Focus on outcome*	Places importance on tangible outputs such as sketches, prototypes, visually interesting designs, required formats and deliverables.	*" ...what the lecturer thinks is interesting... the design is interesting, the lecturer will immediately accept, if the design is not interesting, the lecturer will not accept... "* ***(Respondent ID: 9)***
17.	*Departing knowledge in obscure/ unstructured way*	Departing knowledge in an unclear/unsystematic way, leading to unintegrated, separate pieces of information.	*"... the lecturer wants to explain something to us... but we don't get it... we're still lost... so most students are lost compared to proceeding forwards... "* ***(Respondent ID: 4)*** *"...it's different with the normal subject... like I also don't know what need to be teach because... like it's not systematic like... today, we want to learn this, learn that... it's like very random, the process..."* ***(Respondent ID: 5)***

Appendix E: Principal components factor analysis of participants' learning approaches

Items on *Learning approach*	Factors 1. Deep	2. Strategic	3. Surface
When I'm working on a new topic, I try to see in my own mind how all the ideas fit together.	.57		
Some of the ideas I come across on the course I find really gripping.	.53		
I keep in mind who is going to mark an assignment and what they're likely to be looking for.	.53		
I like to play around with ideas of my own even if they don't get me very far.	.51		
I look carefully at tutors' comments on course work to see how to get higher marks next time.	.51		
I keep an eye open for what lecturers seem to think is important and concentrate on that.	.51		
Regularly I find myself thinking about ideas from lectures when I'm doing other things.	.50		
When I finish a piece of work, I check it through to see if it really meets the requirements.	.49		
Often I find myself questioning things I hear in lectures or read in books.	.46		
I try to relate ideas I come across to those in other topics or other courses whenever possible.	.45		
Before starting work on an assignment or exam question, I think first how best to tackle it.	.43		
It's important for me to feel that I'm doing as well as I really can on the courses here.	.41		
I organise my study time carefully to make the best use of it.		.75	
I usually plan out my week's work in advance, either on paper or in my head.		.65	
I think I'm quite systematic and organised when it comes to revising for exams.		.65	
I work steadily through the term or semester, rather than leave it all until the last minute.		.64	
I generally make good use of my time during the day.		.61	
I don't find it at all difficult to motivate myself.		.61	
I'm pretty good at getting down to work whenever I need to.		.50	
I manage to find conditions for studying which allow me to get on with my work easily.		.49	
There's not much of the work here that I find interesting or relevant.			.69
I gear my studying closely to just what seems to be required for assignments and exams.			.61
Much of what I'm studying makes little sense: it's like unrelated bits and pieces.			.61
I concentrate on learning just those bits of information I have to know to pass.			.60
I'm not really interested in this course, but I have to take it for other reasons.			.57
When I look back, I sometimes wonder why I ever decided to come here.			.56
I find I have to concentrate on just memorising a good deal of what I have to learn.			.56
Often I find myself wondering whether the work I am doing here is really worthwhile.			.45
I like to be told precisely what to do in essays or other assignments.			.43
I often have trouble in making sense of the things I have to remember.			.41

Note. All loadings above .40 are shown.

Appendix F: Principal components factor analysis of participants' learning conceptions

Items on *Learning conception*	Factors: 1. Deep-transforming	2. Surface-reproducing
Seeing things in a different and more meaningful way	,79	
Understanding new material for yourself	,70	
Developing as a person	,69	
Making sure you remember things well		,84
Building up knowledge by acquiring facts and information		,63

Note. All loadings above .40 are shown.

Appendix G: Principal components factor analysis of participants' preference for instruction.

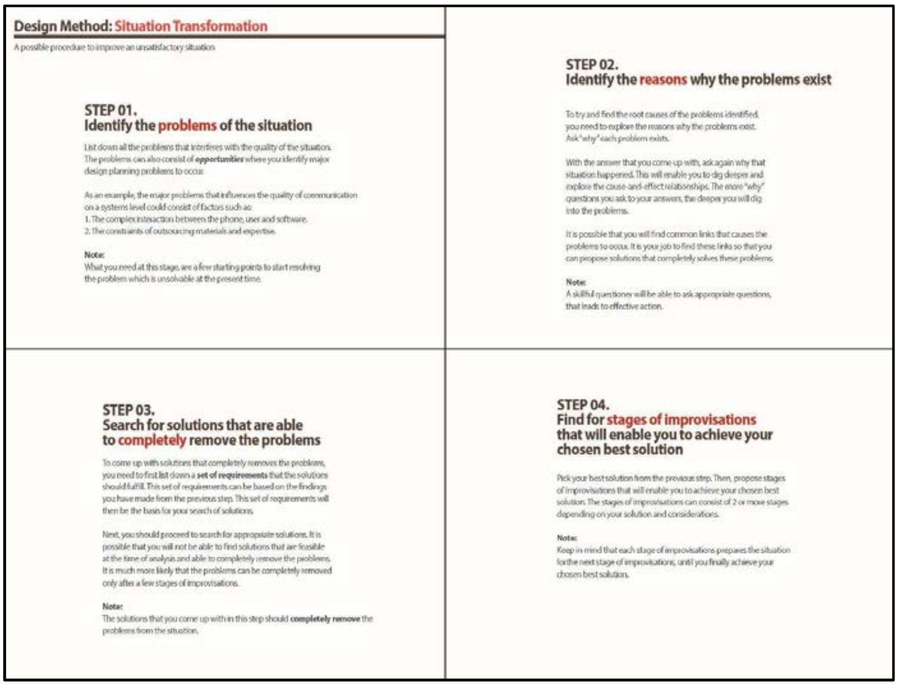
Items on *Preference for instruction*	Factors: 1. Emphasizing Understanding	2. Emphasizing Information
Courses in which it's made very clear just which books we have to read.	,76	
Lecturers who tell us exactly what to put down in our notes.	,74	
Exams or tests which need only the material provided in our lecture notes.	,60	
Books which give you definite facts and information which can easily be learned.	,57	
Exams which allow me to show that I've thought about the course material for myself.		,73
Books which challenge you and provide explanations which go beyond the lectures.		,64
Lecturers who encourage us to think for ourselves and show us how they themselves think		,62
Courses where we're encouraged to read around the subject a lot for ourselves.		,49

Note. All loadings above .40 are shown.

Appendix H: Frequencies of occurrences for the pattern codes: Preference for instruction and learning approaches across all 12 respondents. (D): Deep learning approach, (SF): Surface learning approach, (ST): Strategic learning approach, (I): Teachers that transmit information, (U): Teachers that support understanding.

	Respondents 1	2	3	4	5	6	7	8	9	10	11	12
LEARNING APPROACHES	***D+ ST***	***SF +ST***	***D +ST***	***D +SF***	***D +SF***	***SF +D***	***SF +ST***	***ST +SF***	***ST +SF***	***SF +ST***	***SF +ST***	***D +SF***
Deep (D)	*17*	*9*	*18*	*13*	*57*	*12*	*1*	*0*	*3*	*4*	*5*	*17*
Strategic (ST)	*11*	*14*	*13*	*3*	*6*	*6*	*7*	*10*	*19*	*12*	*8*	*10*
Surface (SF)	*9*	*28*	*11*	*13*	*16*	*15*	*9*	*6*	*6*	*16*	*11*	*16*
PREFERENCE FOR INSTRUCTION	***(U)***	***(U)***	***(U)***	***(U)***	***(U)***	***(I)***	***(I)***	***(I)***	***(I)***	***(I)***	***(I)***	***(U)***
Teachers that transmit information (I)	*2*	*4*	*6*	*7*	*4*	*11*	*10*	*9*	*15*	*14*	*16*	*6*
Teachers that support understanding (U)	*4*	*6*	*8*	*9*	*6*	*7*	*4*	*5*	*5*	*7*	*10*	*13*

Appendix I:Hand-outs of related design theories



Design Method: Situation Transformation

A possible procedure to improve an unsatisfactory situation

STEP 01.
Identify the problems of the situation

List down all the problems that interferes with the quality of the situation. The problems can also consist of **opportunities** where you identify major design planning problems to occur.

As an example, the major problems that influences the quality of communication on a systems level could consist of factors such as:
1. The complex interaction between the phone, user and software.
2. The constraints of outsourcing materials and expertise.

Note:
What you need at this stage, are a few starting points to start resolving the problem which is unsolvable at the present time.

STEP 02.
Identify the reasons why the problems exist

To try and find the root causes of the problems identified, you need to explore the reasons why the problems exist. Ask "why" each problem exists.

With the answer that you come up with, ask again why that situation happened. This will enable you to dig deeper and explore the cause-and-effect relationships. The more "why" questions you ask to your answers, the deeper you will dig into the problems.

It is possible that you will find common links that causes the problems to occur. It is your job to find these links so that you can propose solutions that completely solves these problems.

Note:
A skillful questioner will be able to ask appropriate questions, that leads to effective action.

STEP 03.
Search for solutions that are able to completely remove the problems

To come up with solutions that completely removes the problems, you need to first **list** down a **set of requirements** that the solutions should fulfill. This set of requirements can be based on the findings you have made from the previous step. This set of requirements will then be the basis for your search of solutions.

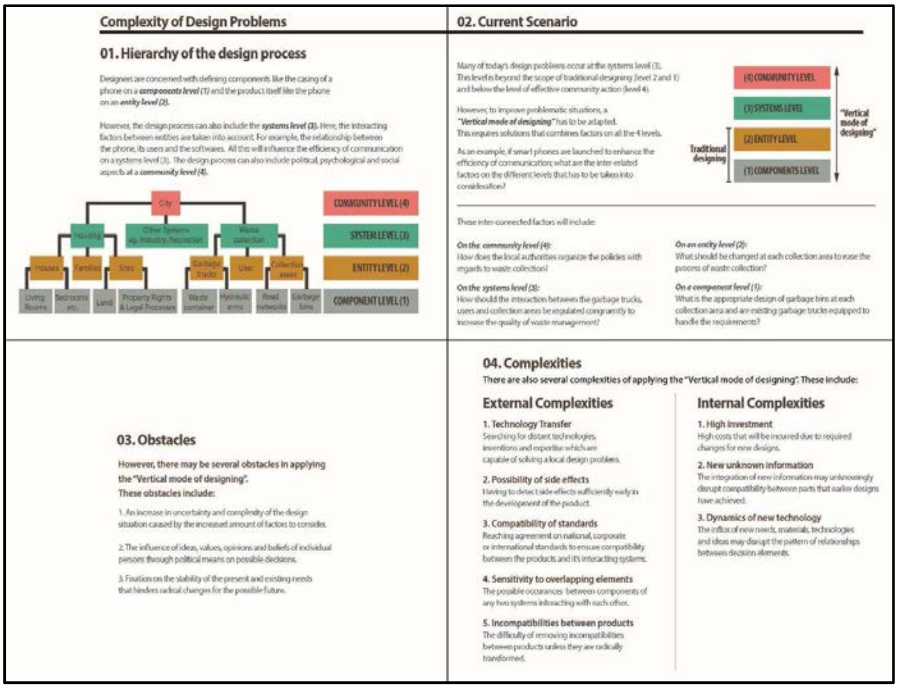
Next, you should proceed to search for appropriate solutions. It is possible that you will not be able to find solutions that are feasible at the time of analysis and able to completely remove the problems. It is much more likely that the problems can be completely removed only after a few stages of improvisations.

Note:
The solutions that you come up with in this step should **completely remove** the problems from the situation.

STEP 04.
Find for stages of improvisations that will enable you to achieve your chosen best solution

Pick your best solution from the previous step. Then, propose stages of improvisations that will enable you to achieve your chosen best solution. The stages of improvisations can consist of 2 or more stages depending on your solution and considerations.

Note:
Keep in mind that each stage of improvisations prepares the situation for the next stage of improvisations, until you finally achieve your chosen best solution.



Complexity of Design Problems

01. Hierarchy of the design process

Designers are concerned with defining components like the casing of a phone on a ***components level (1)*** and the product itself like the phone on an ***entity level (2)***.

However, the design process can also include the ***systems level (3)***. Here, the interacting factors between entities are taken into account. For example, the relationship between the phone, its users and the softwares. All this will influence the efficiency of communication on a systems level (3). The design process can also include political, psychological and social aspects at a ***community level (4)***.

02. Current Scenario

Many of today's design problems occur at the systems level (3). This level is beyond the scope of traditional designing (level 2 and 1) and below the level of effective community action (level 4).

However, to improve problematic situations, a ***"Vertical mode of designing"*** has to be adapted. This requires solutions that combines factors on all the 4 levels.

As an example, if smart phones are launched to enhance the efficiency of communication; what are the inter-related factors on the different levels that has to be takes into consideration?

These inter-connected factors will include:

On the community level (4):
How does the local authorities organize the policies with regards to waste collection?

On the systems level (3):
How should the interaction between the garbage trucks, users and collection areas be regulated congruently to increase the quality of waste management?

On an entity level (2):
What should be changed at each collection area to ease the process of waste collection?

On a component level (1):
What is the appropriate design of garbage bins at each collection area and are existing garbage trucks equipped to handle the requirements?

03. Obstacles

However, there may be several obstacles in applying the "Vertical mode of designing". These obstacles include:

1. An increase in uncertainty and complexity of the design situation caused by the increased amount of factors to consider.

2. The influence of ideas, values, opinions and beliefs of individual persons through political means on possible decisions.

3. Fixation on the stability of the present and existing needs that hinders radical changes for the possible future.

04. Complexities

There are also several complexities of applying the "Vertical mode of designing". These include:

External Complexities

1. Technology Transfer
Searching for distant technologies, inventions and expertise which are capable of solving a local design problem.

2. Possibility of side effects
Having to detect side effects sufficiently early in the development of the product.

3. Compatibility of standards
Reaching agreement on national, corporate or international standards to ensure compatibility between the products and it's interacting systems.

4. Sensitivity to overlapping elements
The possible occurances between components of any two systems interacting with each other.

5. Incompatibilities between products
The difficulty of removing incompatibilities between products unless they are radically transformed.

Internal Complexities

1. High investment
High costs that will be incurred due to required changes for new designs.

2. New unknown information
The integration of new information may unknowingly disrupt compatibility between parts that earlier designs have achieved.

3. Dynamics of new technology
The influx of new needs, materials, technologies and ideas may disrupt the pattern of relationships between decision elements.

Appendix J: Stimulus

What should be developed next?

Appendix K: Brief and task-related information

Transportation problems in the city of Kuala Lumpur, Malaysia

Since the 1980's, the rate of urbanization in Kuala Lumpur has drastically increased. This has led to an increase in the numbers of private transportation. The modes of public transportation has also been unable to cater to the unbalanced rate of urbanization.

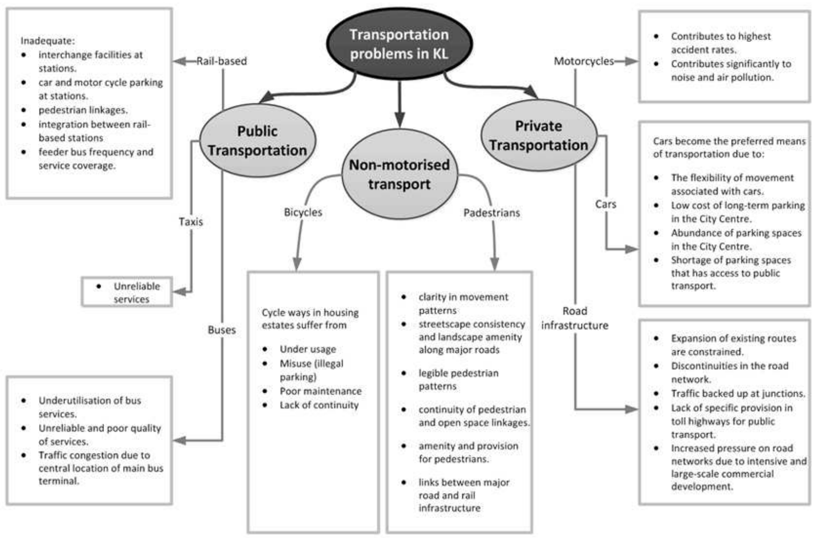
This situation contributes to daily traffic jams and rises political demands for better road infrastructure.

What is your task now?

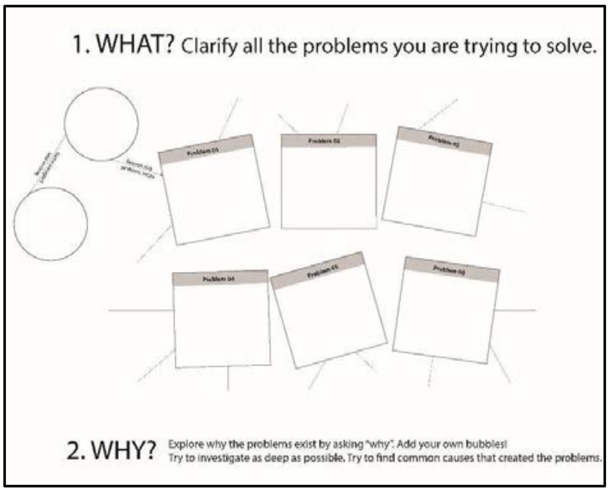
Your task is to **develop around 5 solutions** (it can be 4 or 6**) that will solve this transportation problem completely.** Think about the details of your solutions and do not focus on the quantity of the solutions.

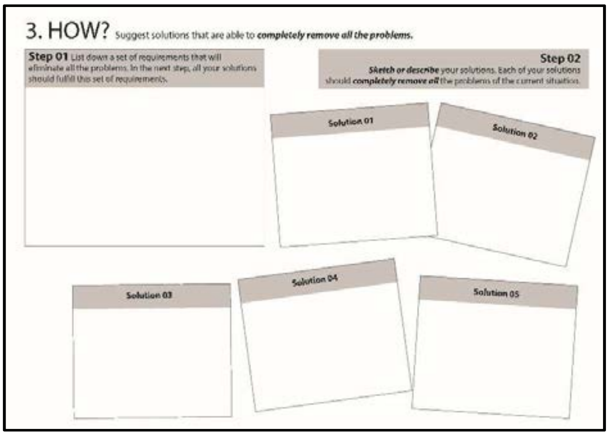
After you have produced your solutions, please **choose and circle your best solution.** Next, **suggest steps** or the **sequence of actions that should be undertaken to achieve your chosen best solution.**

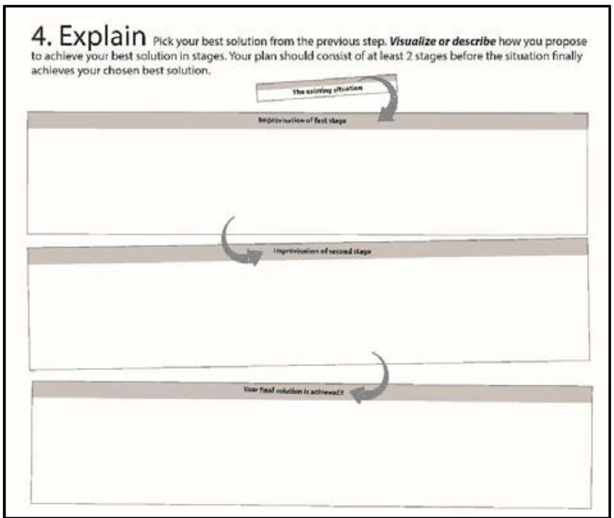
Note: The information below provides you with a few factors that is associated to your task. You can group these factors appropriately and add new factors as deemed appropriate.



Appendix L:Answer templates







Appendix M: Q&A session template

Ref: ______________________________

Name: ______________________________

Q&A Session

1

Please show me your best solution. Tell me how you came up with this best solution.
Tolong tunjukkan penyelesaian terbaik kamu. Bagaimana kamu mendapatkan penyelesaian ini?

2

Did you face any difficulties when doing this task? What kind of difficulties did you face? What did you do to overcome the difficulties? Why did you do that?
Adakah kamu menghadapi sebarang kesulitan semasa membuat tugasan tadi? Apakah kesulitan yang kamu hadapi? Apakah yang kamu lakukan untuk mengatasi masalah tersebut? Mengapa kamu buat begitu?

3

If you could ask your lecturer anything about this task, what would you like to ask him or her?
Jika kamu boleh bertanya kepada pensyarah kamu mengenai tugasan tadi, apa yang ingin kamu tanya kepada dia?

4

What do you feel about the task? Did you feel that you were given too little structured information? Was the information given in a way that you could work with or use well? Did you need any other information? Why do you need that information?
Apakah yang kamu rasakan mengenai tugasan tadi? Adakah kamu merasakan bahawa kamu diberikan terlalu sedikit informasi yang teratur? Adakah informasi yang telah diberikan membolehkan kamu menggunakannya dengan baik? Adakah kamu perlukan informasi tambahan? Mengapa kamu memerlukan informasi tersebut?

5

What about in terms of time, was it too chaotic? Why? If you had more time, what would you have done or done differently?
Bagaimana pula dari segi masa, adakah ia terlalu bercelaru? Mengapa? Jika kamu diberikan lebih masa, apakah yang akan kamu lakukan atau lakukan dengan berbeza?

6

What was new for you when doing this task? Did you learn anything from this task? What did you learn? Do you think that it was important? Why?
Apakah perkara baru bagi kamu ketika membuat tugasan tadi? Adakah kamu mempelajari apa-apa daripada tugasan tadi?
Apakah yang telah kamu pelajari?Adakah kamu merasakan bahawa perkara itu penting? Mengapa?

7

Can you use any new knowledge from this task for future projects? How will you use it?
Adakah kamu boleh gunakan sebarang ilmu baru dari tugasan ini dalam projek-projek akan datang? Bagaimana akan kamu gunakannya?

8

Do you have any questions about this task you had to do?
Adakah kamu ada apa-apa soalan mengenai tugasan tadi?

Appendix N: Questionnaire for Study 2

DESIGN LEARNING SURVEY

University:	Previous education:
Course:	Age:
Year of study:	Gender: Male/Female

This survey has been designed to allow you to describe several aspects associated to your design learning.
For each item below, circle the number that best indicates your relative agreement or disagreement in terms of your learning in your particular design course.
Use the rating scale to select the number.

Part 1	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. I don't find it at all difficult to motivate myself.	1	2	3	4	5
2. When I read, I examine the details carefully to see how they fit in with what's being said.	1	2	3	4	5
3. I concentrate on learning just those bits of information I have to know to pass.	1	2	3	4	5
4. I usually plan out my week's work in advance, either on paper or in my head.	1	2	3	4	5
5. When I am reading, I stop from time to time to reflect on what I am trying to learn from it.	1	2	3	4	5
6. I gear my studying closely to just what seems to be required for assignments and exams.	1	2	3	4	5
7. I generally make good use of my time during the day.	1	2	3	4	5
8. Often I find myself questioning things I hear in lectures or read in books.	1	2	3	4	5
9. Much of what I'm studying makes little sense: it's like unrelated bits and pieces.	1	2	3	4	5
10. I'm pretty good at getting down to work whenever I need to.	1	2	3	4	5
11. Regularly I find myself thinking about ideas from lectures when I'm doing other things.	1	2	3	4	5
12. There's not much of the work here that I find interesting or relevant.	1	2	3	4	5
13. I organize my study time carefully to make the best use of it.	1	2	3	4	5
14. Before tackling a problem or assignment, I first try to work out what lies behind it.	1	2	3	4	5
15. I find I have to concentrate on just memorizing a good deal of what I have to learn.	1	2	3	4	5

1

Part 2	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. I tend to be very frank with people.	1	2	3	4	5
2. It irritates me to have people avoid the answer to my question by asking another question.	1	2	3	4	5
3. I really dislike it when a person does not give straight answers about himself.	1	2	3	4	5
4. It really disturbs me when I am unable to follow another person's flow of thought.	1	2	3	4	5
5. I prefer telling people what I think of them even if it hurts them, rather than keeping it to myself.	1	2	3	4	5
6. I function very poorly whenever there is a serious lack of communication in critique sessions.	1	2	3	4	5
7. When I'm being evaluated in assessments, I feel a great need for clear and explicit evaluations.	1	2	3	4	5
8. If I am uncertain about my responsibilities in a design team, I get very anxious.	1	2	3	4	5
9. At the end of the semester, I might become frustrated because my design would never be completed (design will never be perfect)	1	2	3	4	5
10. Once I start a task, I don't like to start another task until I finish the first one.	1	2	3	4	5
11. Before any important job, I must know how long it will take.	1	2	3	4	5
12. In a problem-solving group it is always best to systematically handle the problem.	1	2	3	4	5
13. A problem has little attraction for me if I don't think it has a solution.	1	2	3	4	5
14. I do not like to get started in group projects unless I feel assured that the project will be successful.	1	2	3	4	5
15. In a decision-making situation in which there is not enough information to process the problem, I feel very uncomfortable.	1	2	3	4	5
16. I don't like to work on a problem unless there is a possibility of coming out with a clear-cut and unambiguous answer.	1	2	3	4	5
17. Complex problems appeal to me only if I have a clear idea of the total scope of the problem.	1	2	3	4	5
18. A group meeting functions best with a definite agenda.	1	2	3	4	5

Part 3	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. Your design capability is something very basic about you that you can't change very much.	1	2	3	4	5
2. You can learn new things but you can't really change how your design capability is.	1	2	3	4	5
3. No matter how much design capability you have, you can always change it quite a bit.	1	2	3	4	5
4. You can always significantly change how intelligent you are.	1	2	3	4	5
5. If you are given another opportunity, you would like to try to do the same task again.	1	2	3	4	5
6. If you are given another opportunity, you would like to try a much more challenging task.	1	2	3	4	5

Please describe how you should have conducted the task?

Finally, can you please indicate how you scored on your design work, so far?

Very Well		*Quite Well*		*Moderately well*		*Not So Well*		*Rather Badly*
9	8	7	6	5	4	3	2	1

Thank you very much for spending time completing this questionnaire; it is much appreciated

Appendix O: Scales for quality of solutions

Scales for Relevance: Applicability

Relevance					
	The degree to which the solution clearly applies to the stated problem.				
	1	2	3	4	5
1. Applicability	Idea/some ideas are not stated or does not produce a useful outcome	Idea/some ideas solves an **implied problem** that is **somehow related** to the stated problem. It may have some benefit within a special situation (do X, which somehow relates to the stated problem)	Idea/some ideas solves an **implied problem** that is **clearly related** to the stated problem (do X to get an implied Y, which applies to the stated problem)	Idea/some ideas solves **1 identified problem** that is **directly related** to the **stated problem** (do X to get Y, and Y is part of the stated problem)	Idea/some ideas solves **2 or more identified problems** that are **directly related** to the 2 **or more stated problems.**

Recommended directions to evaluate:

1. Does solution directly relate to any SP?
   - Yes: 1 SP→ 4 m
     2 SP or more→ 5m
   - No (IP) : Is it clearly related or somehow related?
     Clearly related →3m
     Somehow related →2m
2. Outcome is not useful/ not stated? →1m

Examples of IP from data:

Carpooling → SP1/3
Campaigns → SP1/3
Traffic authorities take action → SP3
New vehicles →SP 3/2
Change working/school hours →SP 3/1
Actions that users have to take (behavioural etc.) →SP 3
Compounds/summons → SP3
***Those categorized as IP, judge based on how solutions are worded to determine whether it is clearly related or somehow related.**

→ (relates to)

Scales for Relevance: Effectiveness

Relevance					
	The degree to which the solution will solve the problem.				
	1	2	3	4	5
2. Effectiveness	Idea(s) are **unlikely to solve the stated problem.** (It probably will not work)	Idea/some ideas **will contribute** to solving **a part of a stated problem.**	Idea/some ideas **will contribute** to solving **several parts of a stated problem.**	Idea/some ideas **will contribute** to solving **a part or several parts of at least 2 stated problems.** (If it can be done, the stated problem will be solved)	Idea/some ideas **will contribute** to solving **a part or several parts of at least 3 stated problems.** (If it can be done, the stated problem will be solved)

Common Examples of evaluation:

- Cycling competitions → 1 m
- Recommended behaviours → 1 or 2 m
- New vehicles →1 or 2 m
- Infrastructures like underground tunnels, add road etc. that solves SP1,3 and 4 → 4 or 5 m
- Limit cars + upgrade public transport solves SP1,2 and 3→ 5m
- Limit cars only solves SP1 → 2m

* Evaluation should be done without regard for workability.

Scales for Specificity: Completeness

Specificity					
Completeness	**The number of independent subcomponents into which the solution can be decomposed, and the breadth of coverage with regard to who, what, where, when, why, and how.**				
	1	**2**	**3**	**4**	**5**
	Contains only one dimension.	Contains 2 different dimensions. **Or** More than 2 parts and 1 dimension	Contains 3 different dimensions. **Or** More than 3 parts and at least 2 dimensions	Contains 4 different dimensions. **Or** More than 4 parts and at least 3 dimensions	Contains 5 or more different dimensions **Or** More than 5 parts and at least 4 dimensions

Scales for Specificity: Implicational explicitness

Specificity					
Implicational explicitness	**The degree to which there is a clear relationship between the recommended action(s) and the expected outcome.**				
	1	**2**	**3**	**4**	**5**
	Expected outcome is not stated, even though it is relevant to the stated problem.	Expected outcome is vaguely stated and is not relevant to the stated problem.	Expected outcome is vaguely stated but is relevant to the stated problem.	Expected outcome is clearly stated but is rather relevant to the stated problem.	Expected outcome is clearly stated and is strongly relevant to the stated problem.
	Expected outcome = NOT STATED	Expected outcome = VAGUELY STATED + NOT RELEVANT TO SP	Expected outcome = VAGUELY STATED + RELEVANT TO SP	Expected outcome = CLEARLY STATED + NOT RELEVANT TO SP	Expected outcome = CLEARLY STATED + RELEVANT TO SP

Recommended directions to evaluate:

1. Refer to Why's coded in "Completeness". Is there a "why"?
   - Yes: Is it related to SP? → 5 m
     Is it **not** related to SP? → 4 m
   - No : Read back if there are any vague indicators of expected outcomes.
     Is there a vague expected outcome?
     - If yes → 1 m
     - If no, is it related to SP?
       - If yes → 3 m
       - If no → 2 m

Appendix P: Chi^2 test (Top: Testing the relationship between the types of questions that students asked and quality of their solutions. Middle: Testing the relationship between students' discerning and opportunistic mind-sets and quality of solutions. Bottom: Testing the relationship between students' receiving hand-out related to design theories and quality of students' solutions.)

Crosstab

			Quality of solutions		
			middle and low outcome	high outcome	Total
Low level questions asked	no	Count	33	3	36
		Expected Count	26,9	9,1	36,0
		% within 25% of high outcome	48,5%	13,0%	39,6%
		Std. Residual	1,2	-2,0	
	yes	Count	35	20	55
		Expected Count	41,1	13,9	55,0
		% within 25% of high outcome	51,5%	87,0%	60,4%
		Std. Residual	-1,0	1,6	
Total		Count	68	23	91
		Expected Count	68,0	23,0	91,0
		% within 25% of high outcome	100,0%	100,0%	100,0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	9,052[a]	1	,003	,003	,002	
Continuity Correction[b]	7,628	1	,006			
Likelihood Ratio	10,135	1	,001	,003	,002	
Fisher's Exact Test				,003	,002	
Linear-by-Linear Association	8,952[c]	1	,003	,003	,002	,002
N of Valid Cases	91					

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 9,10.

b. Computed only for a 2x2 table

c. The standardized statistic is 2,992.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
based on mean score(top and bottom 25% cluster) * DLM	87	95,6%	4	4,4%	91	100,0%

based on mean score(top and bottom 25% cluster) * DLM Crosstabulation

			DLM		
			Discerning Mindset	Opportunistic Mindset	Total
based on mean score(top and bottom 25% cluster)	middle group	Count	33	10	43
		% within based on mean score (top and bottom 25% cluster)	76,7%	23,3%	100,0%
		Std. Residual	-,5	1,2	
	bottom 25%	Count	17	4	21
		% within based on mean score (top and bottom 25% cluster)	81,0%	19,0%	100,0%
		Std. Residual	-,1	,3	
	top 25%	Count	23	0	23
		% within based on mean score (top and bottom 25% cluster)	100,0%	0,0%	100,0%
		Std. Residual	,8	-1,9	
Total		Count	73	14	87
		% within based on mean score (top and bottom 25% cluster)	83,9%	16,1%	100,0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6,181[a]	2	,045
Likelihood Ratio	9,675	2	,008
Linear-by-Linear Association	5,483	1	,019
N of Valid Cases	87		

a. 2 cells (33,3%) have expected count less than 5. The minimum expected count is 3,38.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Whether respondent receives probe or not * DLM_CLUSTER5_lower25Nupper25	91	100,0%	0	0,0%	91	100,0%

Whether respondent receives probe or not * DLM_CLUSTER5_lower25Nupper25 Crosstabulation

			DLM_CLUSTER5_lower25Nupper25			
			middle group	bottom 25%	top 25%	Total
Whether respondent receives probe or not	Probe	Count	24	13	9	46
		% within Whether respondent receives probe or not	52,2%	28,3%	19,6%	100,0%
		Std. Residual	,3	,4	-,8	
	No probe	Count	21	10	14	45
		% within Whether respondent receives probe or not	46,7%	22,2%	31,1%	100,0%
		Std. Residual	-,3	-,4	,8	
Total		Count	45	23	23	91
		% within Whether respondent receives probe or not	49,5%	25,3%	25,3%	100,0%

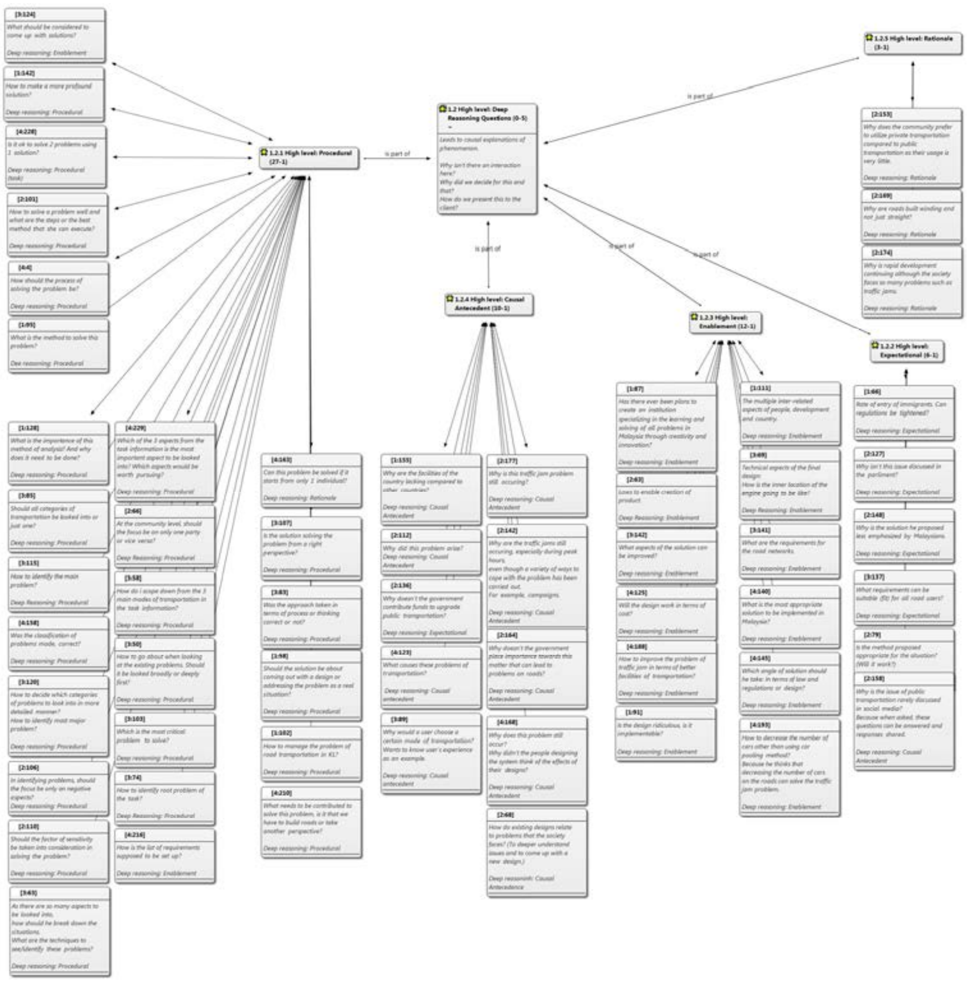
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1,667[a]	2	,434
Likelihood Ratio	1,677	2	,432
Linear-by-Linear Association	,950	1	,330
N of Valid Cases	91		

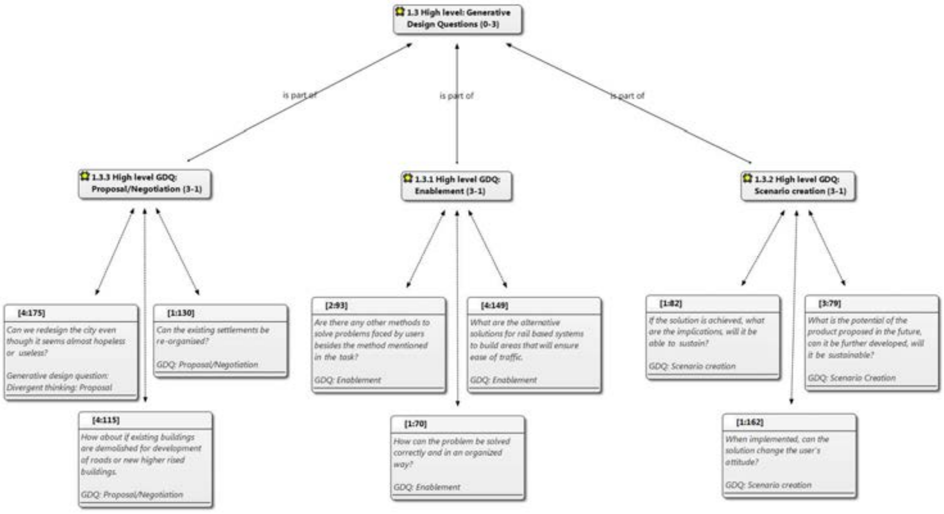
a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 11,37.

Appendix Q: Types of questions asked by the participants

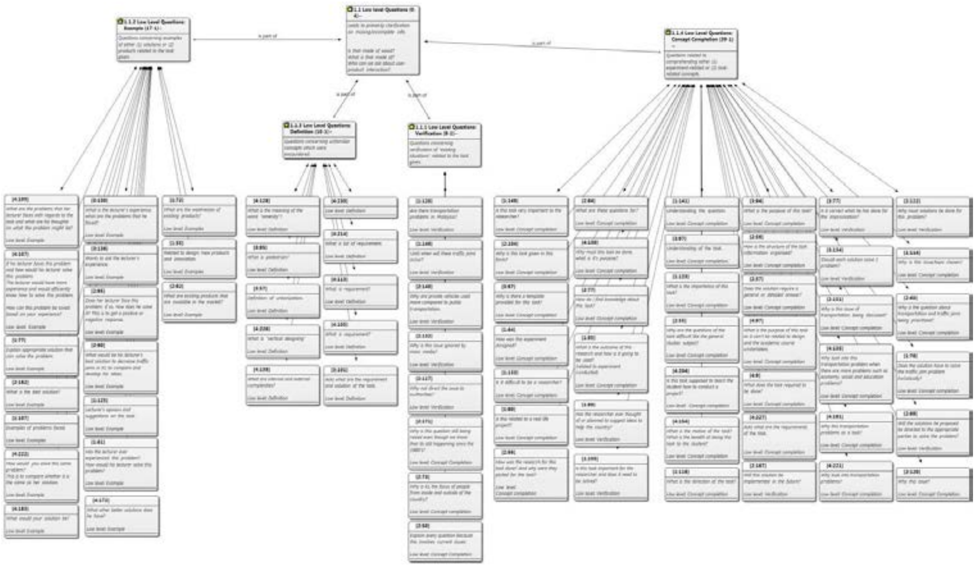
Low level questions



High level questions



Generative design questions



Appendix R: Questionnaire for Study 3

DESIGN LEARNING SURVEY

Name:	E-mail:
Age:	H/P No:
Gender: Male/Female	Previous education stream: Science/ Literature/______________________ (please state)

This survey has been designed to allow you to describe several aspects associated to your design learning. For each item below, circle the number that best indicates your relative agreement or disagreement in terms of your learning in your particular design course.

Part 1	Scales	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. I make an effort to understand new knowledge and concepts quickly.	IKT	1	2	3	4	5
2. When in doubt, I will search for resources on my own.	AE	1	2	3	4	5
3. I am happy if my teacher decides for me how I should proceed with my project	TCM	1	2	3	4	5
4. It is more important for me to have a well thought-out final design than to have a nice presentation for it.	ARA rev	1	2	3	4	5
5. Critique sessions help me see different ways of looking at things.	AR	1	2	3	4	5
6. It is important to me that I come to class so that I can interact with my teachers directly.	IKT	1	2	3	4	5
7. It is important for me to show others how much work and research I have invested in my projects even if this is not as relevant for the final design.	TCM	1	2	3	4	5
8. While designing I tend to use elements, materials or ideas from known/popular design styles because I like them, rather than to reflect about whether they will build a holistic concept.	ARA	1	2	3	4	5
9. I often wonder how designers arrive at their solutions.	AR	1	2	3	4	5
10. I continue to implement tasks my way even if it is done differently by others.	AE	1	2	3	4	5
11. I abandon design ideas if I realize that the final presented model cannot be constructed easily.	TCM	1	2	3	4	5
12. I often find inspiration on the internet, books, etc. while designing but I don't spend a lot of time researching these ideas thoroughly.	ARA	1	2	3	4	5
13. I try to associate information I receive with my design ideas in order to develop it further.	AR	1	2	3	4	5
14. In design projects, I frequently seek feedback from others (teachers, classmates, etc.) on new ideas.	AE	1	2	3	4	5
15. I often depend on teachers to tell me what to do next.	TCM	1	2	3	4	5
16. I usually follow the teachers' instruction without questioning the reasons behind them.	ARA	1	2	3	4	5
17. I usually examine closely the goal of the task that I am supposed to complete thoroughly before starting to design.	AR	1	2	3	4	5
18. I struggle learning things that do not interest me.	IKT	1	2	3	4	5
19. If I encounter new information or design ideas, it is easy for me to give up on my current design.	AE	1	2	3	4	5
20. I will not continue developing an idea further if I realise that it will become difficult to come up with all the necessary details.	TCM	1	2	3	4	5
21. I usually make an effort to understand the purpose/goal behind a design task that is given to me.	ARA rev	1	2	3	4	5
22. I usually try to explore aspects of a project that are not mentioned by the teacher.	AR	1	2	3	4	5

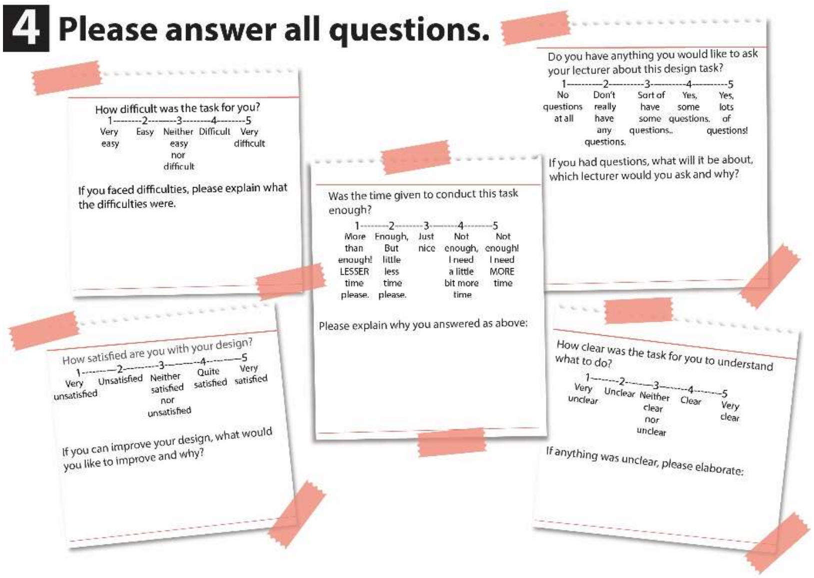
Part 2	Scales	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. I go over the work I've done carefully to check the reasoning and that it makes sense.	ST. ME	1	2	3	4	5
2. I look carefully at tutors' comments on course works to see how to get higher marks next time.	ST. AAD	1	2	3	4	5
3. I try to relate ideas I come across to those in other topics or other courses whenever possible.	D. RI	1	2	3	4	5
4. Often I find myself questioning things I hear in lectures or read in books.	D. UOE	1	2	3	4	5
5. I manage to find conditions for studying which allow me to get on with my work easily.	ST. OS	1	2	3	4	5
6. I organise my study time carefully to make the best use of it.	ST. TM	1	2	3	4	5
7. I find I have to concentrate on just memorising a lot of what I have to learn.	SF. UM	1	2	3	4	5
8. I concentrate on learning just those bits of information I have to know to pass.	SF. SB	1	2	3	4	5
9. There's not much of the work in my design classes that I find interesting or relevant.	SF. LOP	1	2	3	4	5
10. Before starting work on an assignment or exam question, I think first how best to tackle it.	ST. ME	1	2	3	4	5
11. I keep in mind who is going to mark an assignment and what they're likely to be looking for.	ST. AAD	1	2	3	4	5
12. When I'm working on a new topic, I try to see in my own mind how all the ideas fit together.	D. RI	1	2	3	4	5
13. When I read, I examine the details carefully to see how they fit together.	D. UOE	1	2	3	4	5
14. I'm quite systematic and organised when it comes to revising for exams.	ST. OS	1	2	3	4	5
15. I work steadily through the term or semester, rather than leave it all until the last minute.	ST. TM	1	2	3	4	5
16. I gear my studying closely to just what seems to be required for assignments and exams.	SF. SB	1	2	3	4	5
17. When I look back, I sometimes wonder why I ever decided to come here.	SF. LOP	1	2	3	4	5
18. When I finish a piece of work, I check it through to see if it really meets the requirements.	ST. ME	1	2	3	4	5
19. I keep an eye open for what lecturers seem to think is important and concentrate on that.	ST. AAD	1	2	3	4	5
20. I like to play around with ideas of my own even if they don't get me very far.	D. RI	1	2	3	4	5
21. It's important for me to be able to follow the argument, or to see the reason behind things.	D. UOE	1	2	3	4	5
22. I usually plan out my week's work in advance, either on paper or in my head.	ST. OS	1	2	3	4	5
23. I generally make good use of my time during the day.	ST. TM	1	2	3	4	5
24. Much of what I'm studying makes little sense: it's like unrelated bits and pieces.	SF. UM	1	2	3	4	5
25. I often have trouble in making sense of the things I have to remember.	SF. UM	1	2	3	4	5
26. I like to be told precisely what to do in essays or other assignments.	SF. SB	1	2	3	4	5
27. I'm not really interested in this course, but I have to take it for other reasons.	SF. LOP	1	2	3	4	5

Finally, can you please indicate how you scored on your design work, so far?

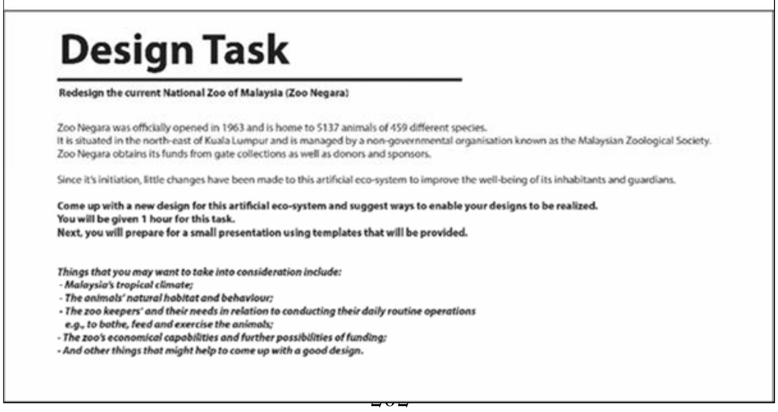
Very Well		*Quite Well*		*Moderately well*		*Not So Well*		*Rather Badly*
9	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*

Discerning mind-set	IKT	Interest in knowledge
	AE	Active experimentation
Opportunistic mind-set	TCM	Taking convenient measures
	ARA	Administering routine actions
Discerning/Opportunistic (reverse items)	AR	Active/Inactive reflection
Deep LA	D. RI	Relating ideas
	D. UOE	Use of evidence
Strategic Monitoring LA	ST. ME	Monitoring effectiveness
	ST. AAD	Alertness to assessment demands
Strategic Management LA	ST. OS	Organised studying
	ST. TM	Time management
Surface LA	SF. UM	Unrelated memorising
	SF. SB	Syllabus boundedness
	SF. LOP	Lack of purpose

Appendix S: Questionnaire on task



Appendix T: Design brief used in the quasi-experimental study for Control group (Top) and Experimental group (Bottom)



Appendix U: Scales for assessing the quality of solutions

Clarity of solutions

Refers to the degree to which the solution is communicated well.

1	2	3	4	5
Not clear at all	Marginally clear	Somewhat clear	Clear	Very clear

Scale	Definition
1	Solution is completely ambiguous and incoherent.
2	A large part of the solution is ambiguous or incoherent.
3	A small part of the solution is ambiguous or incoherent.
4	Solution is coherent but requires effort to be understood.
5	Solution can be understood easily.

Completeness of solutions

Refers to the degree to which the solution will thoroughly solve the problem.

1	2	3	4	5
Not complete at all	Marginally complete	Somewhat complete	Complete	Very complete

Scale	Definition
1	The solution does not solve the given problem and/or solves an unrelated problem.
2	The solution is related to the problem, but unlikely to solve the problem.
3	The solution is reasonable but contributes to only a small part of the problem.
4	The solution is reasonable and contributes to a big part of the problem.
5	The solution is reasonable and is very likely to solve the problem.

Usefulness of solutions

Refers to the degree to which the solution benefits the stakeholders involved (the animals, it's guardians and visitors)

1	2	3	4	5
Not useful at all	Marginally useful	Somewhat useful	Useful	Very useful

Scale	Definition
1	The solution poses considerable disadvantages to the stakeholders involved.
2	The solution poses slight disadvantages to the stakeholders involved.
3	The solution poses neither disadvantages nor benefits to the stakeholders involved.
4	The solution poses slight benefits to the stakeholders involved.
5	The solution poses considerable benefits to the stakeholders involved.

Feasibility of solutions

Refers to the degree to which the solution can easily be produced/implemented (in terms of manufacturing, technology and existing facilities)

1	2	3	4	5
Not feasible at all	Marginally feasible	Somewhat feasible	Feasible	Very feasible

Scale	Definition
1	It will be very difficult to implement the solution.
2	It will be rather difficult to implement the solution.
3	It will be neither difficult nor easy to implement the solution.
4	It will be easy to implement the solution.
5	It will be very easy to implement the solution.

Originality of solutions

Refers to the degree to which the solution is rare, completely new and surprising (among other solutions produced).

1	2	3	4	5
Not original at all	Marginally original	Somewhat original	Original	Very original

Scale	Definition
1	Solution exists, common, mundane, boring.
2	Solution is slightly interesting and/or differs from existing solutions.
3	Solution is fairly interesting and/or considerably differs from existing solutions.
4	Solution is unusual and shows some imagination.
5	Solution is very unexpected, imaginative or surprising and entirely questions the problem definition.

Appendix V: Reliability of questionnaire scales

Scale	Cronbach's Alpha	Original number of items	Number of Items
Mind-set			
Discerning	0.76	12	7
Opportunistic mind-set	0.71	15	13
Learning Approach			
Deep	0.69	6	5
Strategic	0.78	12	8
Surface	0.72	9	6

About the author

Basyarah Hamat was born in Singapore, on 12 December 1984. She obtained her BSc in Industrial Design from University Teknologi Malaysia and Masters in Digital Media in the University of Adelaide, Australia. Upon graduating from her Bachelor's degree, she was employed as an assistant industrial designer by Orcadesign Consultants Sdn.Bhd. Here, she was involved in the conceptual design phases of product design projects for companies such as Ambi Pur, HP and Stabilo. Subsequently, she joined University Teknologi Malaysia as a tutor in the industrial design department, where she was assigned to teach design. The challenge of teaching design as a novice teacher led her to her current research topic. Even as a student, she was incessantly inquisitive about how students learned to design. With the individual differences that exist within each student, how did they learn to create well-informed designs? Furthermore what can be done to improve their design learning? In July 2013, Basyarah received a doctoral grant from the Ministry of Higher Education, Malaysia. She joined the Design Theory and Methodology section of the Product Innovation Management department in TU Delft, and embarked on her 4 year journey to answer the abovementioned questions. In addition to her research , Basyarah has also been involved in supervising students in their first year research course and final Bachelor graduation project.

List of conference publications

Hamat, B., Badke-Schaub, P., & Eris, O. (2015). Design Learning Mind-sets. In C. Weber, S. Husung, G. Cascini, M. Cantamessa, D. Marjanovic, & M. Bordegoni (Eds.), *International Conference on Engineering Design, ICED15* (pp. 341–350). Milan, Italy. Retrieved from https://www.designsociety.org/publication/38020/design_learning_mind-sets

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Manuscript submitted for Journal Publication

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