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A heuristic to understand curriculum change:
towards comparing 3 course programme overhauls within the Dutch 3TU coalition

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INTRODUCTION

The 3TU coalition consists of the three universities of technology in the Netherlands: Delft, Eindhoven and Twente, which are all-round engineering universities. The 3TU Centre for Engineering Education (CEE) was incepted September 2014 and it allows the universities to engage with engineering education in a more structured way. In recent years the three universities overhauled their bachelor programmes to improve the learning experiences of the students and, ultimately, improve graduation rates and diminish time to graduation. Such projects are not usually documented in such a way that the process and outcomes can be easily understood and this limits the capacity of an organisation to learn from such projects. In this first project of the CEE the overhaul processes are mapped, evaluated and compared ex post facto using heuristics that were developed specifically to understand curriculum change in the context of engineering education. The goal of this paper is to present the heuristic that will be used in this project and some preliminary experiences with the heuristic as a research instrument.

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1 HEURISTICS FOR CURRICULUM CHANGE IN ENGINEERING EDUCATION

1.1 Engineering education as the pivot of heuristics for curriculum change

The special focus in this project is the uniqueness of developing and implementing engineering course programmes. Engineering is an interdisciplinary field where scientific knowledge is applied to design solutions to solve complex problems in an "engineering kind of way" (see e.g. [1, 2]). This creates many challenges for those who design course programmes, but also for those who implement them and this is reflected in the goals of engineering curricula and to some extent in the way these curricula are implemented (see e.g. [2, 3]). The heuristic developed in this project needs to include elements pertaining to attributes of engineering education, attributes of successful change and attributes of successful interventions. The research questions informing this study was: What are the elements of a heuristic for the development of an engineering curriculum?

1.2 Method of heuristics development

The heuristic is based on a literature review and a small number of interviews with stakeholders. The literature review was performed late 2014 and included professional reports, research papers and books. The interviews were done with several directors of education at Delft University of Technology and with experienced curriculum change consultants from all universities involved.

2 LITERATURE REVIEW ON CURRICULUM CHANGE

Curriculum design as we know it is mostly based on the Tyler rationale [4]:

1. What educational purposes should the university seek to attain? (Defining appropriate learning objectives.)
2. How can learning experiences be selected which are likely to be useful in attaining these objectives? (Introducing useful learning experiences.)
3. How can learning experiences be organized for effective instruction? (Organizing experiences to maximize their effect.)
4. How can the effectiveness of learning experiences be evaluated? (Evaluating the process and revising the areas that were not effective.)

These principles are still generally applied when curriculum change is being contemplated and apply to different levels of education: the university level, the classroom level and the level of learning tasks. These principles do not say anything about the *conditions* necessary for the curriculum to function properly or how it should be implemented for optimal learning results. Clark, Froyd, Merton and Richardson [3] report that real curriculum change in engineering education is very hard and often seems impossible. What often happens is that when the curriculum is redesigned, de facto nothing changes: the course content, teaching approach, and culture stay the same. In the most comprehensive and engineering-specific research paper on curriculum change to date Borrego and Henderson [5] compared change strategies in engineering education. They reported four categories of implementation strategies, each with two sub-strategies, as presented in Table 1. Borrego and Henderson do not go into the question of which strategy is the most successful, but they observe that the most successful approaches incorporate multiple strategies for change. If curriculum change is intended as a way to restructure the curriculum entirely, it seems that categories 1 and 2 are elements of change that is implemented on the policy level.

Table 1 Summary of change categories and strategies. Borrego and Henderson, 2014.

Change category and strategy	Summary	Key change agenda role	Key change mechanism	Typical metrics of success
1 Curriculum & Pedagogy				
Diffusion	Innovations are created in one location, then adopted or adapted by others. Multi-stage adoption process.	Develop a quality innovation and spread the word.	Adaption decisions by potential users.	Number of users or amount of influence of the innovation.
Implementation	A set of purposeful activities are designed to put proven innovations into practice in a new setting.	Develop a training programme that involves performance evaluation and feedback.	Training of potential users.	Fidelity of use of innovation.
2 Reflective teachers				
Scholarly teaching	Individual faculty reflect critically on their teaching in an effort to improve.	Encourage faculty to reflect on and collect data related to their teaching.	Evidence-based reflection on practice.	Self-reported changes in beliefs, teaching practices or satisfaction with student learning.
Faculty learning communities	A group of faculty supports each other in improving teaching.	Bring faculty together and scaffold community development.	Peer support/ accountability, exposure to new views about teaching and learning.	Self-reported changes in beliefs, teaching practices, or satisfaction with student learning.
3 Policy				
Quality assurance	Measurable target outcomes are identified and progress towards them is assessed and tracked.	Develop measurable outcomes, define success, collect evidence.	Pressure to meet outcomes.	Degree to which outcome measures are met.
Organisational development	Leader develops new vision and plans a strategy for aligning employee attitudes and behaviours with this vision.	Develop new vision. Analyse alignment of parts of the organisation with the new vision and identify strategy for creating alignment.	Strategic work by the leader to communicate vision and need for change and to develop structures to motivate employees to work towards it.	Productivity-related metrics (e.g. credit hour production, graduation rates, etc.).
4 Shared vision				
Learning organisation	Leader works to develop an organisational cultural that supports knowledge creation.	Move decision-making further from the top. Invest in developing employees' personal mastery, metal models, shared vision, team learning.	Team-level questioning revision of mental models (i.e. double loop learning) facilitated by middle managers.	Vague and situation dependent.
Complexity leadership	In a complex system results of actions are not easily predicted. Change agents can create organisational conditions that increase the likelihood of productive change.	Disrupt existing pattern, encourage novelty and act as sense makers.	New ideas emerge through interactions of individuals. Formal leaders encourage this process by creating disequilibrium and amplifying productive innovations.	Vague and situation dependent.

Stolk, Somerville and Chachra [6] identified three models for curriculum design in engineering education: the 'just do it' model, the 'It's an engineering design problem' model and the 'community approach'. They observed that all these models are highly product-driven, that the focus was on the course content and learning outcomes, and there was relatively little mention of the teachers who will engage with the courses. Curriculum design was only a part of educational change: "… a rational solution to an identified need may not be sufficient to catalyse change within an organisation. Large group adoption and implementation of curricular changes requires a consideration of context and socio-cultural factors" [6, page 2]. Stolk et al. postulated that the values present in any group that is confronted with curricular change should play a larger role in the entire process of change. Clark, Froyd, Merton and Richardson reported from a study that mapped changing mental models of curriculum change leaders overtime: "[the leaders] began to recognise that curricula are dynamic entities, and

they began to see that the role of educators is to guide change. They learned that curriculum is an agreement between all of its constituents and curricular changes are negotiations, not just constructions of syllabi and learning activities" [3, page 45]. The importance of communication on intended changes to the curriculum should therefore not be underestimated [7]. Many teachers work from profound personal beliefs on teaching and learning and share values and attitudes towards teaching within smaller discipline oriented communities. Lattuca, Terenzini, Harper and Yin studied the implementation of new Accreditation Board for Engineering and Technology (ABET) standards in different fields of engineering education and found that the field mattered to the extent to which the standards had been adopted [8]. This is in line with Stolk et al. who advised that organisation culture should play a major role in the design and implementation phases [6].

All in all it seems that just picking and choosing strategies from the list given by Borrego and Henderson is not enough for designing and implementing new curricula successfully [5]. Graham studied the conditions for successful curricular change and reported a number of recommendations for engineering universities and departments who seek to change their programmes [2]. These recommendations pertain to the phases of preparation, planning, implementation and of sustaining the change. The recommendations are strongly based in practice and research. Godfrey and Parker [1] described the core of engineering in 6 characteristics which we paraphrase here: an engineering way of thinking (prevalence of maths and visual communication, a focus on problem solving and design and awareness that there is no single best way of doing things), an engineering attitude and a 'can do' mentality, limited acceptance of non-engineering viewpoints, and person- and thing orientation (see also: [9, 10]). It is safe to assume that these attributes of engineering play a role in any systemic change in Engineering Education.

Besides strategies and characteristics of core engineering, there are more factors to take into account for a successful change. Communication for instance is an important part of acceptance of change, and it should preferably be done in a visual manner. Graham [2] also identified that the perceived need for change is an important factor for successful change. In section 3 we present the heuristic in a table containing those factors that are important to address for a successful change in engineering education are listed.

3 A HEURISTIC FOR CURRICULUM CHANGE

Table 2 Heuristic for describing curriculum change.

	Variable	Description	References
A	Context		
1	Attributes of faculty and course programme	1. Short description of the programme of the content, including learning objectives and key numbers concerning graduation rates, duration, percentage of switchers, negative recommendations on continuation of study (BSA), female/male students.	[11, 17]
2	Faculty culture regarding education	1. Attitude and beliefs of management and teachers regarding the course learning goals and final objectives. 2. Attitude of management and teachers regarding education in general. 3. What is the proportion of time spent on research and education?	[8]
B	To what extent have the changes regarding the curriculum been implemented effectively?		
4	Necessity of changes	1. What was the reason for these changes? Was there external and/or internal pressure? 2. Most important issues/ problems regarding the programme. 3. Problems experienced by students, management, teachers and other actors such as Department of Education, alumni, employers of graduates. 4. Who is the problem-owner?	[2, 11]
5	Goals of the innovation	1. Is there a new vision formulated? 2. Which goals were formulated: regarding the curriculum, the organisation of the	[2, 11]

		curriculum and the faculty as a whole. 3. Is there a prioritization of these goals? 4. To what extent are these goals specific to engineering? 5. What are the educational foundations underneath the goals. 6. Are these goals part of a shared vision? 7. What are the projected results? What are 'must haves' and 'wish to haves'. 8. Is there is final date for when the goals need to be achieved.	
6	Preparation	1. Which sources/documents were consulted? Literature, reports, individual accounts, etc. 2. Which documents were drawn up in the preparation process? 3. What role did these documents plan in the planning phase and when? 4. Was there anything left unchanged in the programme? Which part was this and why? 5. Who were involved in the preparations? Why were these persons selected and what roles did they take on? 6. How and how often did the teams communicate with the other and with the wider community? 7. Was there any kind of resistance towards the change in the organisation? Where in the organisation did it occur and how were these dealt with? 8. How many resources were available for those involved in terms of time? 9. How is the impact of the change evaluated and monitored? 10. What role was given to the quality control officer/unit in the evaluation and monitoring activities?	[2, 7]
7	Implementation	1. What implementation strategy was chosen? How does this strategy tie into the strategies identified by Borrego & Henderson: curriculum & pedagogy, reflective teachers, policy, shared vision or a combination of these? 2. Who were involved in the preparations? Why were these persons selected and what roles did they take on? 3. What were the catalysers and barriers in the process of implementation? Who or what were these and when did they occur? 4. How and how often did the teams communicate with the other and with the wider community? 5. Was there any kind of resistance towards the change in the organisation? Where in the organisation did it occur and how were these dealt with? 6. How many resources were available for those involved in terms of time? 7. When were the supporting officers (rostering, etc.) involved in the process? 8. Were there any guidelines for the developers and for professionalising teachers? 9. Was there monitoring in place and if yes, what was monitored by who? 10. What role did quality control play in the implementation of the change? 11. How did those involved preserve momentum for the change and process?	[2, 5, 12]
8	After implementation	1. Is the status quo of the change satisfactory to those involved in the change? 2. What data is currently monitored and why? 3. How do those involved keep the organisation's focus on the change? Is it enough? 4. How is dealt with unforeseen issues that are the consequence of the change? 5. What is still left undone? What does still need to be improved? 6. How is sustainability taken care of?	[2]
C	Have the changes in the curriculum been effective in terms of attributing to achieve the course's final terms?		
9	Description of the curriculum change	1. What are the exact changes that were designed and implemented and what are the rationale and considerations underlying these changes? Is the change evidence-based? 2. Was a vision formulated? What was this vision and who formulated it? 3. Were new learning objectives developed in terms of knowledge, preparation for society, personal development and competences? 4. Was there a clear alignment between the new learning objectives and the change itself? 5. To what extent have courses been integrated? What is the position of the arts and social sciences in the new curriculum? 6. Do the changes reflect the ideas on the engineer that is an expert in his own discipline and knows how to connect it with other disciplines?	[7, 13]
10	Student engagement/ satisfaction with the curriculum	1. What teaching and learning activities are included in the curriculum and to what extent are these activities intended to activate for the students? 2. To what extent are student-centred learning and assessment activities viewed as an integral part of student support? 3. To what extent are student-centred teaching and learning activities viewed as an integral part of student retention policy and aimed at helping students to find their feet in the programme? 4. To what extent does the institution organise and facilitate capacity, understanding, skills and opportunities for all students to be engaged and successful? 5. Do students feel at home in the programme and at the faculty? 6. How are students supported to optimise their success? 7. How does the programme deal with resit exams, retake assignments and study	[6, 14]

		delays? 8. How does the programme challenge students to develop good study habits and attitude? Is there coaching available for students?	
11	Do-ability*	1. To what extent is the programme aimed at do-ability*? 2. How is the course load spread out over the semesters? 3. How and how often are students assessed? 4. How is programme do-ability and student engagement monitored? What data is collected? 5. How many credits on average do the students obtain per semester and in the first year? 6. How many students leave the programme and when? 7. What is known about how students spend their time? How much time do they devote to their studies? 8. How are grades distributed in each course and how does that compare to the old programme?	[15, 16]
*Do-ability pertains to the absence of barriers in the programme, but also about the extent to which students are challenged to make decisions that affect their success positively.			

4 PRELIMINARY ANALYSES AND REFLECTION ON THE HEURISTIC AS RESEARCH INSTRUMENT

In the Spring of 2015 the interviews and document analyses were executed and the heuristic was put to the test to describe a broad range of changes in two programmes that are offered in all three universities of the 3TU coalition. These programmes are Architecture and Built Environment[2] and Electrical Engineering. All interviews were transcribed and the transcripts and documents were analysed using the labels and key elements of this heuristic. In this section we discuss the experience of analysing the interview transcripts using this heuristic. The results of the analyses will be published elsewhere.

Section A: collecting information on programme attributes was to be relatively easy, but collecting data on the faculty culture and attitudes proved to be much harder. On a basic level in every faculty there is a group of people who are enthusiastic about and committed to bachelor education, but the size of this group varies and the amount of time these people have to spend on education varies too. We found that the heuristic is not very specific when it comes down to this concept and a methodological issue here is that people who are not engaged in education would not surface to participate in the research we did. An addition to the heuristic is that these issues are all about the perceptions of culture by those involved in the curriculum change.

Section B: from the interviews it showed that the necessity of changes was clear and accepted by academic and teaching staff, but that the consensus on goals of the programmes or the way to arrive there differed. In some programmes people disagreed on whether the T-shaped engineers should start specializing in the bachelor, rather than in the master. This seemed to us an important issue that needed to be tackled: on the surface there seemed to be consensus and understanding, but in practice people still had different interpretations of the issues at stake. The heuristic worked well in identifying these differences and making it easier to get to the root of issues in the curriculum change process.

From the conversations it became clear that in the minds of staff preparation and implementation are the same thing: in the preparation phase the implementation needs to be addressed. The real implementation then comes down to finalizing alignment between courses and solving unforeseen issues in practice. If the

[2] At the University of Twente there is no separate programme in Architecture and Built Envinroment, but building physics is offered within the context of civil engineering.

preparation is thorough, the number of unforeseen issues obviously diminishes. In one programme the retake exam schedule proved to be troublesome when implemented. In retrospect the responsibility should not have been put with the module coordinators, but with the director of education who oversaw the curriculum as a whole. In another university the module coordinators where also given this responsibility. This was done for two reasons: 1, to give the module coordinators their own freedom and responsibility so they would feel ownership and 2, because the programme director also didn't know the for sure what the best solution would be, the module had to play out first. In one of the universities the care after the implementation was mostly in the hands of the quality control officers and in both cases the procedures and focus of the quality control was discussed and changed in the preparation and implementation phases, but in practice these procedures needed to be fine-tuned too. In one of the other universities the implementation was mostly in hand of the curriculum commission and the module coordinators. Quality control officers could be consulted when needed and where more involved in monitoring. Some of the platforms for alignment and discussion fell away after the preparation phases, which made it harder for some of the coordinators to find natural moments to talk to colleagues about relevant matters and alignment. In the programme of a different university monthly module coordinator meetings were scheduled to discuss relevant issues and alignment.

Section C: the description of the change proved to be straightforward, but it was very difficult to learn about the effects of the changes shortly after its implementation. Within the programmes officers looked for pass rates and grades and compared these to previous years. The impressions of the teachers on the level of mastery of the students played an important role in the assessment of the effects of the new curriculum. On the engagement of students it is mostly teachers' impressions that play a role. Students are asked to provide information in the evaluations, but in all cases these are voluntary and anonymous, so it is not easy to deduce a lot of information on engagement. In some programmes it was decided to evaluate per education period, which provides useful information on alignment and engagement. Studies on how students spend their time are a useful addition to the information from the course evaluations. An addition to the heuristic could be to ask staff to reflect on the students' reported experiences, as it is important to know how staff deals with student feedback, which is an important element of a safe learning environment and a reflection of the culture in a faculty of programme.

5 CONCLUSIONS AND DISCUSSION

Curriculum change is not a simple endeavour and there have been many authors who attempted to write guidelines for curriculum development and implementation.

The goal of this paper was to develop a heuristic that will be used to document course programme overhauls within the 3TU coalition in the second phase of our project. This heuristic may serve as a tool for pioneers who are to embark on a curriculum change, who seek to implement or evaluate efforts in curriculum change.

The preliminary experiences with applying this heuristic as a research instrument were positive: it helped to structure the narrative of the change process and it helped to clarify misunderstandings that evolved before, during and after the process. We do not claim to be complete, but at least this list of relevant topics and questions can serve as a checklist for a large number of relevant items that need consideration when curriculum overhaul is contemplated.

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