A NEW ADAPTIVE E-LEARNING CONCEPT FOR MULTIDISCIPLINARY LEARNING ENVIRONMENTS

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ABSTRACT

Engineering is a broad multidisciplinary discipline, also reflected in the increase of the variety of students in a single academic course in terms of foreknowledge and of interests and skills. Adaptive learning is a powerful tool to achieve tailored education in a multidisciplinary learning environment. Students with a diverse background and even with different levels can work together in a similar learning environment. Without support of e-learning concepts and online tools, this method is however very time consuming and ineffective for the lecturer.
E-learning modules are typically passive, not directly guiding the students. The new concept presented here, actively helps the student to develop their own learning route, based on their needs and interest, yet meeting the course's learning objectives. The overall concept is based on a plenary core set of lectures embedded in a flexible shell of adaptive e-learning modules. These modules are cross-linked allowing the student to step from one topic branch to another, depending on the need or interest identified by a brief end-of-module assessment and earlier information collected by the system.
A basic version of the web-based application to guide students through the network of e-learning modules is tested and showed positive results in terms of student appreciation yet not directly in terms of performance. The latter is the most relevant from a didactic point of view, while the success of the concept heavily relies on the positive student appreciation. The outcome of these first test used as input for the development of the final application.

KEYWORDS

Adaptive Learning, Multidisciplinarity, Blended learning, Engineering, Web-based tool, ICT, Standards: 1, 5, 8

INTRODUCTION

The ever-changing and developing society constantly requires professions that did not exist twenty years ago. Students have to become professionals capable of steering their own career development and capable of controlling their own learning process, now and in their future profession. Multidisciplinarity is a relevant key challenge in the Science, Technology, Engineering and Mathematics (STEM) disciplines. The multidisciplinary character answers to the needs of the industry: multidisciplinary engineers are demanded to solve the challenges the industry currently and in the future faces. These challenges range from design to end-of-life related, and from highly technical to – for example – more logistic problems.

Multilevel education is relevant as well: students enter courses or educational programs with different levels of foreknowledge and intended or required output level. The term multilevel broadens the "Personalized Learning" concept by including a variation in student foreknowledge level, e.g. MSc, Post-MSc and PhD.

These two elements are in particular relevant for the Mechanical Engineering master specialization Maintenance Engineering and Operations (MEO), offered by the faculty of Engineering Technology (ET) of the University of Twente (UT). MEO crosses borders between departments in and even between faculties: the research group Industrial Engineering and Business Information Systems (IEBIS) of the Behavioural, Management and Social science (BMS) faculty, also contributes to the track.

The influx of students in the MEO courses exhibits a high diversity: they are following a master track in Mechanical Engineering (ME), Industrial Design Engineering (IDE) or Industrial Engineering (IE), have a BSc degree in one of these directions or in Advanced Technology (AT) or Electrical Engineering (EE). In addition, an increase in influx from post-master students (PD-Eng – a 2 year post-MSc program – and PhD) is observed, requiring flexibility in the exit level. New educational methods are deemed necessary to accommodate all this.

The key challenge is how to offer a flexible program, allowing students to make choices (Personalized Learning or Student Centred Learning (Richmond, 2014)), yet also to guide them through the selection process, while assuring the learning goals of the course are met. None of the currently existing educational models meets these requirements, thus a research project is initiated. Its objective is to adjust and morph existing techniques, combining and integrate them with state of the art supportive techniques, such as offered by ICT.

The novel concept is based on a blend of plenary lectures, a flexible shell of adaptive e-learning modules and an interactive guidance and selection tool. Using adaptive e-learning modules is recognized as a powerful tool to overcome the challenges identified (Kamardeen, 2014, Marković, Jovanović, Jovanović, Jevremović, & Popović, 2013). The students have the possibility to compose their own, individual program of learning modules, satisfying both their needs and interest. Shifting responsibilities in the learning process to students, leading to a more active engagement of the students, is shown by Freeman et al. (2014) to have a positive effect in particular in STEM disciplines. The students should however be guided in their selection, recognizing what is relevant to them. Boelens, De Wever, & Voet (2017) point out that self-regulation is a necessary, yet for some students, difficult skill. Although online lectures, e-learning and e-teaching methods, both static and adaptive have been implemented (Kamardeen, 2014, Marković et al., 2013), the extent to which they are blended with plenary lectures is limited (Boelens et al., 2017). Modules are implemented as separate entities of the course, while a strong linking between the modules is envisioned here.

The navigation through the network of e-learning modules requires:

- a well-defined structure relying on a decision tree (Song, Singleton, Hill, & Koh 2004);

- input based on the student's selection of modules and on the student's level of understanding of those modules. This information can be acquired prior to following an e-learning module, or in an adaptive way during participation in a module. Learning analytics is an important means (Jovanović, Gašević, Dawson, Pardo, & Mirriahi 2017);
- the incorporation of feedback mechanisms, to inform students and lecturers on the performance and to inform the students on the suggestions for other modules to follow. The feedback currently greatly depends on the lecturer's skills and available time to answer to questions in fora on applications such as Blackboard (Rovai & Jordan, 2004).

The novelty of the proposed blended learning concept is the supporting guiding system for the students to navigate through and select modules. This sets the method apart from the more standard application, based on a series of not interconnected (micro-)lectures and no or limited feedback, let alone guidance. As a first step in this research, a network of learning modules is built, including guidance and basic feedback for the students, for the first year BSc course Statics of the Mechanical Engineering and Industrial Design Engineering programs of the University of Twente. The learning modules were provided to the students who failed the first test and were preparing for the re-take. The objective of is to investigate the appreciation of the students of the concept and the effect in terms of understanding of the course topics. The results are evaluated by individual feedback of the students on the use and usefulness of the basic adaptive learning tool developed and by examination of the exam results. The results will be used as input for further development and implementation of the tool.

THE ADAPTIVE BLENDED LEARNING TOOL

Structure of the Tool

The general structure of the concept is shown in Figure 1. First of all, the core Intended Learning Outcomes (ILO) must be defined. The additional ILO's are however not optional, but may be met at a certain, pre-specified minimum level. Here, a distinction can be made between multidisciplinary courses, for which the concept is initially developed, and mono-disciplinary courses, see also Table 1. In a multidisciplinary course, a basic level of knowledge is expected on all fields, while specialization in a certain direction requires the student to master ILOs of that discipline. The additional ILOs for the mono-disciplinary courses are more supportive to reaching the core ILOs. The objective is to enhance the fundamental knowledge of a specific topic by providing more learning material. Topics that are mastered by the student do not need to be followed. The underlying mechanisms to guide the students through the network (Figure 1) are very similar. Logical, conditional statements are used to guide the students. Such a conditional statement can for example be either "if you are interested in discipline *X*, then you may also be interested in discipline *Y*" or "If you do not understand topic *X*, then you may also not understand topic *Y*", in case of a multidisciplinary or mono-disciplinary course respectively.

It is therefore of utmost importance to define the ILOs both accurately and in a hierarchical way. It is important to recognize that some disciplines or topics are more important to master completely than others. Consultation with colleague lecturers of the same or linked master specializations (e.g. MEO) or learning lines (e.g. Mechanics or Mathematics) is strongly advised if not essential.

For the course of Structural Health and Condition Monitoring, it is evident that the students must have a fundamental understanding of the concept of monitoring. On the other hand, the way the monitoring is executed, the algorithms used, the sensors used, are all in the domain of (sub) specialization. For the mono-disciplinary courses it is important to identify from which concepts a fundamental understanding is essential. Making a Free Body Diagram (FBD) is an essential starting point. Making one of a composed structure, or from a section of the structure are less general examples. Some students will need more support before they are able to apply the general concept of making an FBD to these more specific cases.

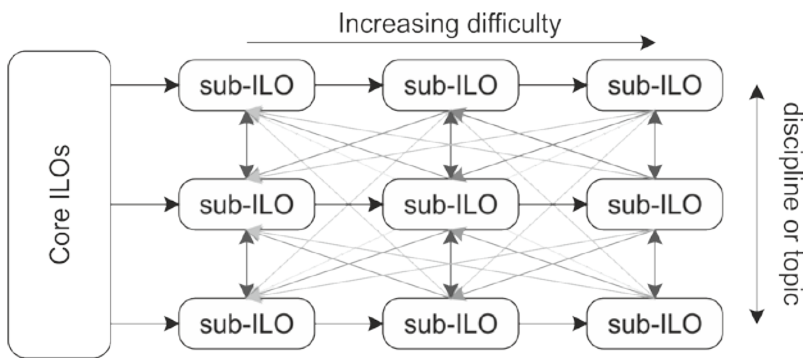

Figure 1. Network of core and related sub ILOs. Horizontal lines: modules treating a certain discipline or topic. Students are guided over the network (arrows).

Table 1. The differences in modules for multidisciplinary and mono-disciplinary courses.

ILO	Multidisciplinary	Mono-disciplinary
Core	General knowledge and insights related to the course content, overarching various disciplines.	Basic knowledge of the course, as a bare minimum, sufficient for above average student to meet the ILOs
Sub	Specializations in different disciplines, partly elective.	Topics addressed in more detail and with increasing complexity or completeness.
	Student must reach a preset minimum level in each discipline, depending on the required output level.	Student follows as many levels as necessary to gain sufficient understanding of the topic to meet the ILOs
	Student must reach a preset minimum level in the direction of specialization.	

Another important difference between the levels is the method of lecturing. The core level ILOs are lectured in a more direct way, with the minimum distance between student and lecturer, while the ILOs of the other levels are taught in a more distant manner through video lectures and/or pencasts or similar options. This blended form is deemed necessary to optimize the effectiveness of the learning process (Asarta & Schmidt, 2017). This effectiveness includes student appreciation, as a higher appreciation results in a higher commitment of the students and an increased effort by them (Padhi, Rajasekhara Babu, Jha, & Joshi, 2019). This also stimulates peer review; giving, receiving and processing feedback from peers is a valuable learning mechanism (Boud, Cohen, & Sampson, 2014).

The layers with the sub-ILOs are typically organized in an e-learning setting, using e.g. video lectures and pencasts. This provides the necessary flexibility for the students, as well as guidance in their choices (Boelens et al., 2017). The challenging aspect is to identify the needs of the student, without direct interaction of the lecturer. In a passive mode, the students provide information on their foreknowledge. Active methods involve queries that the students must make.

In the particular example discussed in this paper, the background of the students is known in a more or less passive way: the students using the adaptive learning tool all failed the first test and are preparing for a re-take. This is still a diverse group, but in general, their knowledge level and skills are below average. Typically, the averaged mark and pass rate, as well as the highest mark are lower than that of the first exam.

Development of the Tool

The basic adaptive blended learning tool is developed for the course Statics, a first year, first term course of the BSc programs of Mechanical Engineering (ME) and Industrial Design Engineering (IDE) at the University of Twente. The students of the two programs follow the same course, be it lectured at different hours during the week and by different lectures. However, all materials (book, exercises, lectures slides) are the same. The written exam is also the same for both groups and made jointly by the lecturers. The part of the lectures can be considered as the core of the course (see Figure 2).

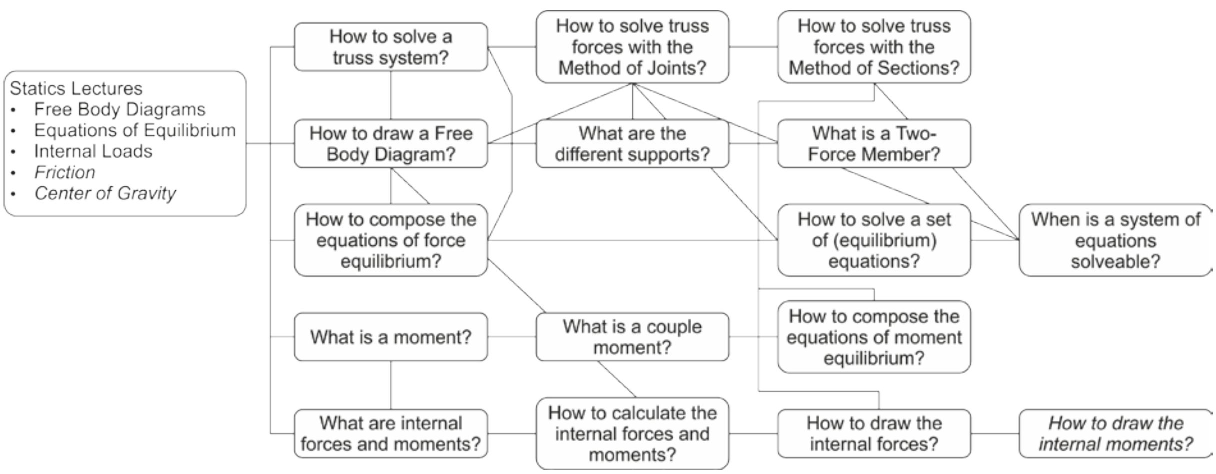

Figure 2. Learning modules (pencasts) for the course Statics. The lines indicate the connections between the different modules. The italic parts are not yet developed.

The first exam was taken as a starting point (which is why there is a module on solving truss systems), as the prime focus of the tool was to prepare the students for the exam. This does not imply that only exam questions are treated in the tool, but it rather makes it a top-down than a bottom-up approach: the questions of the exam are used to highlight and clarify the general concepts of Statics. A pencast is made for each topic, using an iPad and the software Explain Everything. These pencasts are subsequently stored as video file (mp4) and uploaded to Vimeo. The settings are set such that only someone with a direct link can find the video.

A pdf document is made with a series of multiple choice questions. In some cases, the student is asked to first watch an instruction video (external link to a pencast uploaded to Vimeo), but in the majority of cases the student has to answer the test questions immediately. The student can then view the answer (internal link in the document) and compare it to the answer given. These answers provide brief information why a certain answer is either correct or wrong and suggest specific instruction videos (external link to Vimeo location). The structure is visualized in Figure 3.

The given structure requires a thorough design of the questions: specific errors must be implemented, without making the answer very obvious. One option is to base the errors on the errors students make during the written exam. The idea is that the students will make the same mistake here, even though the correct answer is also listed. A construction in which this works quite effectively is to ask the student to e.g. sketch a so-called Free Body Diagram (FBD) of a certain structure. Then, the students are asked to compare their answer to a set of FBDs and the conditional logic starts: “If your FBD corresponds best with answer *X*, then [feedback *Y* is given] and it is advised to watch instruction video *Z*”. In some cases multiple instruction videos can be advised, although it is best to keep this number limited.

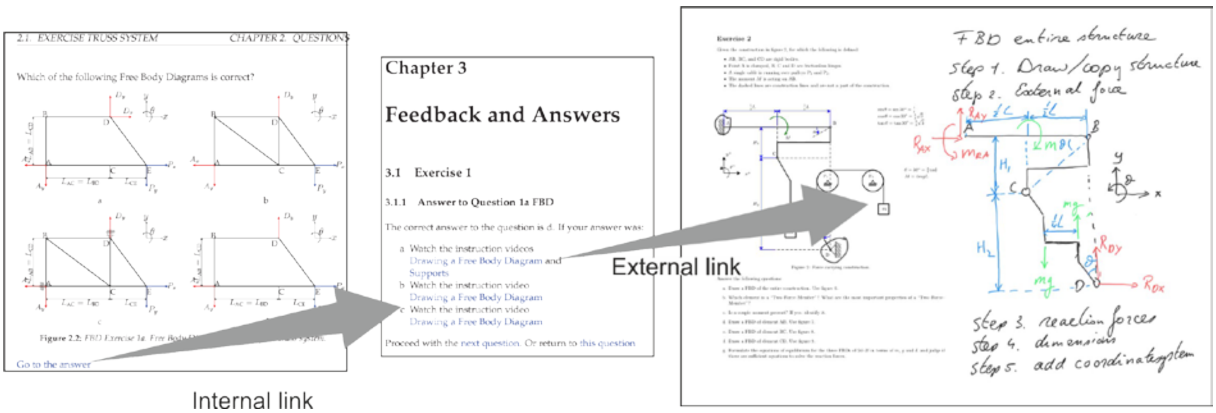

Figure 3. Document structure from question via an internal link to the answers and via an external link to a pencast (mp4 uploaded to Vimeo).

Another form that is used is a list of statements from which more than one is correct. Again, the questions should be formulated carefully. Some questions are deliberately very much alike, such that the student must really know what is true and what is not true. Alternatively, a statement is repeated later in the list, with a different formulation, to check the consistency of the answers of the student. An example of a list of questions, on the properties of a truss system and the analysis of these systems, is:

“Which of the following statements is true (multiple answers possible)

a. One can choose the direction of the forces in the trusses arbitrarily.
b. A truss system consists of Two Force Members only.
c. A truss system consists of Two Force Members only, apart from the elements that are connected to supports.
d. The method of joints is easier than the method of sections.
e. The method of sections can only be used if the forces in a limited number of trusses is asked.
f. An arbitrary number of trusses can be cut to create sections.
g. The method of joints does not require moment equilibrium.
h. A single coordinate system must be used for all FBDs when using the method of joints.
i. Each force in a truss is a vector, hence there are two unknowns: the two components of the two orthogonal directions *x* and *y*.”

Statements b and c are very similar and test the details of the knowledge of the students. Both statements g and i link to statement b, as they are consequences of the truss consisting of so-called Two Force Members. Answering these questions wrongly, indicates the students have insufficient overview of the consequences of certain principles in the theory. For example, if they did not include answer g as a correct answer, then they are advised to follow the instruction video on what a moment is, but in addition to the instruction video on Two Force Members, as it is addressed there why no moment equilibrium is required.

The entire process requires some discipline from the students. To stimulate correct use of the document, it starts with an instruction, not only explaining how the document works, but also how it should be and should *not* be used.

RESULTS AND DISCUSSION

A Google form based questionnaire was sent to the students, to investigate their experience with the tool and the effectiveness of it. Unfortunately, the number of respondents is low (11 out of 114), which is a common problem with digitally sent questionnaires. Students receive a large number of questionnaires, making them less willing to complete yet another one. The questions were organized in different categories: General perception; general use, level of difficulty of the questions, instruction videos, learning effect and appreciation. These questions had to be rated (5 levels, from fully disagree to fully agree). Two open questions were added ("What aspects of the ABL tool were most useful or valuable?" and "How would you like to see the ABL tool to be improved?"), followed by an overall rating of the tool (score 1-10), an field for additional comments and additional, optional, information regarding the study program they follow and gender. The results are graphically represented by the radar plot in Figure 4, showing each category with a different background color. The squares indicate the mean score for each question, while the size of the grey circles indicate the frequency of each score for each question.

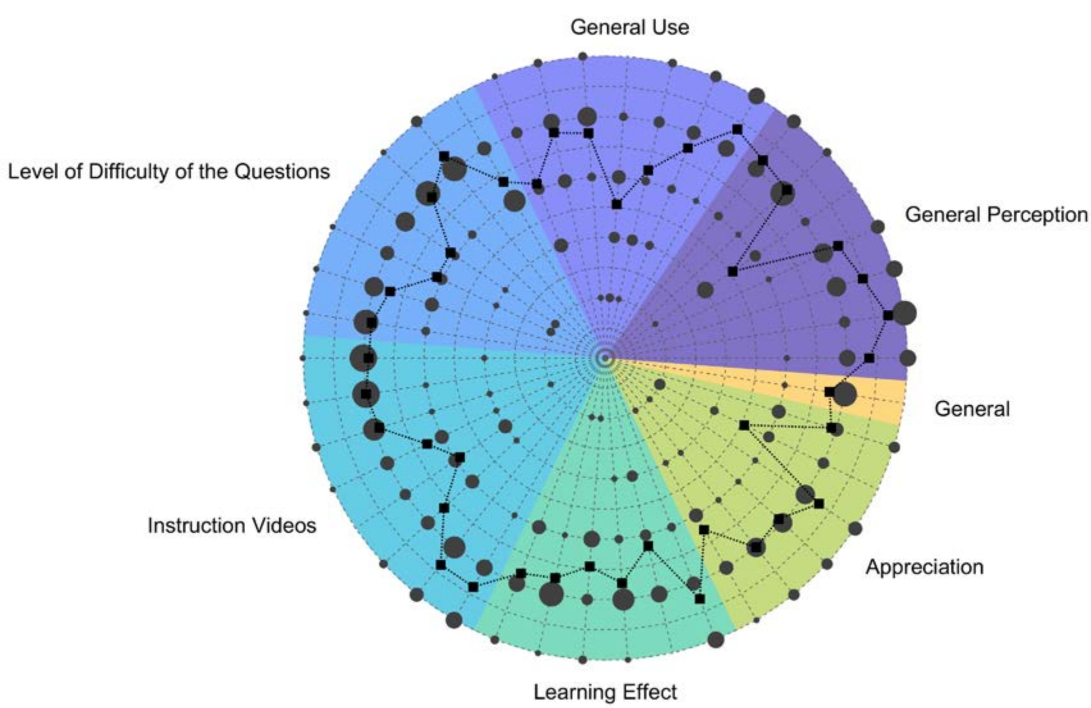

Figure 4. Radar plot of questionnaire results. The black squares indicate the mean, the size of the grey circle the number of times that score was given while the colors refer to the different categories of questions.

All respondents were positive about the document and in particular the instruction videos. This last point is not entirely unexpected, as long and extensive instruction videos were already made, explaining how to answer the questions of a previous exam. These videos were well received and multiple requests for making more of these videos were received by the author. Extensive, written documents are also available for the students, explaining the answers to the exam questions in virtually as much detail. Key elements explaining the appreciation of the students for the pencasts are the more dynamic and visual explanation compared to the static text, the possibility to pause and rewind the pencast and explicit visualization of how an answer is built up. These aspect are all included in the pencasts of the adaptive blended learning tool.

The one low score in this category was for the question "Jumping back and forth in the document and to the videos is disturbing". A pdf with internal and external links is a rather basic form of an e-learning application, not particularly optimized for user-friendliness. According to Song et al. (2004), this is a key element in the student appreciation of an e-learning application, hence it is positive that the score is low in this question.

More variation and a lower score was observed for the questions in the category "general use" on reviewing videos. This kind of repetition can be useful, but a good score for skipping suggested videos if the student already mastered that topic hints to an effective use of the tool: study time is spent on the topics the student do not master well.

The level of difficulty and the quality of the videos were both awarded with high scores, indicating a good level was found for teaching the course theory. However, lower scores are given for the questions relating the problem presented and discussed in the tool and the exam questions: students indicate that a better match with the exam questions would have been better and that the tool did not prepare them for the exam. At the same time, most respondents indicate they had the feeling their understanding of the course content was increased by the using the tool. In a one-to-one setting with some of these students, the author noticed that indeed the level of understanding was significantly better than the mark for the first exam suggested, although it was not reflected in the mark for the re-take. This is partly attributed to the fact this exam was prepared by the ME lecturer of the course, who is new to educating first year students. The formulation of the exercises and balance of the test was different and consequently the results are not a good measure for the effect of the adaptive tool on the performance. However, it did reveal that there is a gap between the student's perception of understanding and their actual understanding.

The underlying mechanism here, may be the predominantly qualitative learning environment of the students. Starting at primary school, students are graded and the limit mark for passing becomes a target by itself, while understanding the concepts of a course is less important (Yorke, 2003, Gikandi, Morrow, & Davis, 2011). In response to the issues with the re-take, oral exams with some IDE students were scheduled. These oral exams showed a reasonable to good understanding of the students, but a limited ability to apply the knowledge in a more general way. This indicates a gap exists between possessing and applying knowledge. Formative assessment is an important concept to change the student's attitude and it is recommended to explore the possibilities to embed this in the tool to steer the students towards fundamental understanding and improve their ability to apply their knowledge.

Overall, the respondents mark the course highly (7.5 out of 10 on average). This is a clear sign that the method of learning is well appreciated, which is also confirmed by the scores in the appreciation category. The lower score is for the question whether this tool can replace lectures. Together with the high score for the question whether the course can equally well be studied by using the written material, indicates that the students consider it an addition, which is in line with the intentions of the tool: it is complementary to the lectures.

It was suggested in the open comment section that open questions would be better than multiple choice questions. The choice for multiple choice was forced given the technical constraints and time limitations faced during the development of the tool. The fact that the correct answer is given, be it amidst incorrect answers, does allow for recognition rather than deduction or derivation of the answer. This can be mitigated by using multiple choice questions in a smart way. Some questions were shaped such that the student first had to answer a question (e.g. sketch an FBD), which is the nearest to an open question that the tool got. The right attitude is required from the student. It is therefore recommended to investigate how the adaptive learning tool was used to fully assess its effect on the output level of the students.

CONCLUSIONS AND FUTURE OUTLOOK

The following can be concluded:

- Students appreciate the concept of being guided to elements of theory they understand less, giving them a feeling of better understanding;
- For this case, the students perception of their level of understanding does not match their general level of understanding, while the tool aims to stimulate the latter;
- Multiple choice questions may allow for recognition rather than deduction and derivation, implying proper attention to the development of the questions is paramount.

The results obtained here, will be further used in the tool to be developed. The next steps include the following aspects:

- Professionalization of the recording of the pencasts
- Exploration of the use of formative assessment to stimulate general understanding;
- Exploring the possibilities to enrich the way questions are asked, to mitigate the possibility of answer recognition;
- Embedding of the tool in the digital learning environment;
- Implement the tool in a course.

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BIOGRAPHICAL INFORMATION

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Alberto Martinetti is an assistant professor in the chair of Maintenance Engineering within the department of Design, Production and Management. He is track coordinator of the Maintenance Engineering and Operations specialization in Mechanical Engineering at the University of Twente and has worked for the Polytechnic of Turin and for the University of Turin. He holds a Master's degree in Geo-resources and Geo-technologies Engineering (2009) and a PhD degree in Environmental and Land / Safety and Health at the Polytechnic of Turin (2013) on Prevention through Design approach in mining activities.

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