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Integrated assessment of disciplinary, personal and interpersonal skills in a design-build course

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ABSTRACT

Integrated assessment of functional disciplinary knowledge and personal and interpersonal performance is discussed in the context of a final-year design-build course. The course is intended to consolidate disciplinary knowledge through individual and teamwork efforts in an authentic design-build project. There is a coupling between approaching the task and practicing personal and interpersonal competencies. We believe that personal, interpersonal and disciplinary knowledge are mutually supportive and learned together. The learning objectives do therefore explicitly include knowledge, skills and attitudes related to personal, interpersonal and product and system building skills, as well as disciplinary skills. Since the assessment should reflect the course objectives a procedure for integrated assessment of the above mentioned competences was developed.

There are some aspects of the course that are troublesome to students:

- Students' attitudes to knowledge are challenged. Some have a "right-or-wrong" view on technical knowledge, and question the nature and validity of knowledge in the personal and interpersonal sphere. They are also further challenged here by a more relativistic view on technology and engineering.
- Some students have difficulties to recognise and appreciate the learning in this course. The focus on synthesis, consolidation and application of also quite fundamental technical knowledge differs from the way students have previously seen knowledge being evaluated, for instance in exams.
- The distinction between reaching the project goals (building a product that flies or floats as required) and meeting the course goals (learning outcomes).

The design of the assessment system must be informed by the full complexity of the student learning experience, or assessment risks undermining the learning outcomes. Drawing on qualitative data from several cohorts of students, extracted from learning activities, interviews, questionnaires etc, we discuss and interpret students' responses to the challenges, and how they perceive the learning experience, especially in relation to their attitudes towards knowledge. We describe our assessment system, where peer assessment and feedback are elements.

INTRODUCTION

The topics discussed are related to a project course given during the final year of a Masters education in engineering. In the following, a brief description of the intent with the course is given, i.e. the curricular purpose, the format, aim and learning objectives of the course.

Extending the Learning Objectives

One of the cornerstones within the CDIO initiative is that personal and interpersonal knowledge, skills and attitudes should be explicitly addressed during the engineering education. The demand for such competences was obvious from a survey conducted by the four original schools in the early CDIO initiative [1]. There was a striking agreement between the replies from people working at different levels in industry and in academia, in the United States and in Sweden, indicating that emphasis should be put on communication skills, teamwork training, and development of personal skills and attitudes.

The motive for addressing these skills and attitudes to the engineering profession is thus that there is a demand for such competences, both in academia and in industry.

The Role of the Course in the Curriculum

The course in focus is given during the final two semesters of a Masters programme in vehicle engineering, and in terms of course credits it constitutes a quarter of the students' workload during their fourth year. The course is referred to as a capstone course, meaning that it is designed to stimulate the students to synthesise and reinforce knowledge. This is achieved through work related to a concrete problem statement in a project environment. The students come from two different specialisation programmes, allowing the project to be somewhat cross-disciplinary and thereby contain technically conflicting interests and mismatch problems in a realistic manner. In a sense, the course is intended to train application of knowledge in a similar fashion as the subsequent thesis work, but more emphasis is put on challenges specific for technical work in a project group environment, such as planning, technical communication, documentation, technical negotiation and compromising, decision making, et cetera. In addition, all projects are intended to lead to real physical results, which is not always the case in thesis work. In theory, the outcome could be software. It is however essential that the outcome could be verified with respect to a technical specification.

The Course Format, Aim and Learning Objectives

The work is carried out as projects where approximately 10 students work together towards mutual project goals. A typical project task is to design and build a vehicle that meets a specification of requirements, given a set of constraints in terms of budget and time frames. The group is given responsibility both for the planning and the execution of the work and typically a few of the students take on leading roles in project management while the decision making is usually handled democratically by the entire group. The bulk of the technical work is delegated to smaller teams within the group, which carry out subtasks and report back to the large group. After completing the course the students are supposed to be able to

- work effectively in a project environment and understand mechanisms behind progress and difficulties in such a setting
- communicate in writing, orally and graphically

- analyse problems from a systems (holistic) perspective
- use modern engineering methods and tools
- handle technical problems which might be incompletely stated and subject to multiple constraints
- realise own ideas practically
- assess the quality of technical work, performed by themselves or others

As seen in the course goals above the learning objectives are not only, or purely, technical. It is the outspoken intent with the course to teach and train personal and interpersonal skills together with disciplinary knowledge in the context of a technical project.

The Pedagogical Approach
The project task constitutes the incentive for the students to become involved in all the activities included in the course. The product of the project is a vehicle, both literally and figuratively speaking. From a pedagogical perspective the product is simply a means to reach the learning objectives. Once the physical vehicle has been completed its role as a learning vehicle ends.

The course work is formed around the project task and the responsibility for planning and distributing the work within the group is delegated to the students. They are encouraged to consult the course instructors for advise and guidance on the approach and execution of the different subtasks. Once a subtask is completed it is reported back to the large group by means of a written report and an oral presentation. The course instructors give a number of seminars to support the process, addressing various aspects of the project work. When found necessary tutorials are given in order to support or direct critical phases in the analysis. Occasionally, dedicated group exercises, called workshops, are arranged to boost the progress of specific activities. Although the course instructors keep regular contact with the students carry out the bulk of the work in absence of the instructors.

INTEGRATED LEARNING AND ASSESSMENT

Integrated Learning
We believe that personal, interpersonal and disciplinary knowledge to a certain extent are interdependent and therefore they should be learned and assessed together. We strongly question the perception of personal and interpersonal skills as generic and transferable. That would imply that they can be learned and assessed separately and then applied regardless of the context, but in our experience there is no foundation for that assumption.

Take communication skills as an example. Even if there are certain aspects of communication skills that are generic, and let us even for a moment assume that they are transferable, in this course the intended learning outcomes related to communication are much deeper. We want students to acquire the ability to communicate technically, both with experts and laypersons, and nurture confidence in expressing themselves within their field of work. What must then be practised and assessed is authentic performance. For instance the students are expected to be able to describe and present ideas and, if necessary, argue for or against conceptual ideas and solutions. They should further be able to develop ideas through collaborative sketching and engineering

reasoning. The communication skills in this course are deeply embedded in, and inseparable from, students' application of technical knowledge. Learning and assessing communication in a reductionist manner is simply not appropriate.

Integrated Learning Demands Integrated Assessment

Assessment is the most powerful tool we have to guide and support student learning. It is the assessment system rather than the espoused learning objectives that communicates the real learning objectives to the students. At least to the students "*it is not the curriculum that shapes assessment, but assessment that shapes the curriculum*" [2]. In this course, personal and interpersonal competencies are integrated in the intended learning outcomes, thus they must be given reasonable attention in the assessment system. In this course, this is especially important since the students who come to the project course have not attended a CDIO programme during their earlier years in the programme, as the programme is still in transition. Taking CDIO learning outcomes seriously is therefore contrary to students' earlier experiences in the programme. It is therefore important to clearly show that they are not just added to the learning objectives to pay lip service, but are legitimate and required learning outcomes of the course.

As discussed above, it is not enough to assess the personal and interpersonal competencies separately. We hope for the students to develop contextualised skills, and they must therefore be assessed in context. Based on this, our conclusion is that integrated learning demands integrated assessment.

The Assessment System

The design of the assessment system must be informed by the full complexity of the student learning experience, or assessment risks undermining the learning outcomes. If we restrict the assessment to the easily measurable outcome of the work, such as reports, presentations and the physical products of the project, we might not effectively persuade the students to develop the intended competences. We chose to use peer assessment as a means to collect the students' opinions and as feedback on the performance of each other. This is firstly because one of the learning outcomes is that students should be able to assess the quality of their own and others' technical work, but also because the main part of their work is unsupervised so the teachers do not have full insight.

The assessment process is sequenced in the following way. All elements described are mandatory course activities and preceding instructional and subsequent reflective seminars are given to support them.

Course goals

In the beginning of the course the students are asked to express their personal course goals, as a complement to the formal learning objectives.

Narratives

Throughout the course the students are responsible to document and gather evidence for their contribution to the project. This portfolio is presented as a comprehensive narrative and the narratives of all students are distributed within the group.

Feedback and suggested grades
The students write feedback to each other, guided by a number of rubrics such as analytical, practical, social and administrative contribution. Finally, they are suggesting a summative grade for each of their colleagues. Each student receives the feedback from each colleague plus the average of the suggested grades.

Group discussion
The students and course instructors discuss the narratives of each student, one at the time. The owner of the narrative initially takes part of the discussion in order to clarify the contents but is then leaving the room allowing the rest of the group to discuss the quality and quantity of the contribution of the described work. The instructors chair the session, specifically ascertaining that the discussion is kept objective and focussed.

Course reflections
The students write a reflective document on their experiences from the course, to what extent they have reached their personal course goals as well as the formal learning objectives in the course.

The narratives, feedback and course reflections are first written as a mid-course exercise and there are several benefits with this poll. Firstly, it gives the students a chance to test-fly the assessment system and practise giving and receiving feedback. Secondly, it provides the students with some feedback on their performance to date, giving them an opportunity to actually respond to the opinions of their colleagues during the second half of the course. Thirdly, it actualises the difficulties to objectively judge the work by others and to give constructive and relevant feedback.

DISCUSSION

While we are happy to observe that a great majority of the students reach the learning outcomes in a reasonably effective manner, and almost every student praises the course lavishly. Still, in our experience, there are some aspects that can be troublesome to some of the students, and that we need to address in order to support the learning experience. In the following we discuss some troublesome aspects that are related to students' perceptions [3] of knowledge and learning. The quotes used for illustration originate from several cohorts of students, and are extracted from interviews, reflection documents and documentation from learning activities.

Students' Attitudes to Knowledge are Challenged.
Some students come to the course with a dualist, "right-or-wrong", view [4] on technical knowledge. It is common that students hesitate to use their prior knowledge, and they do not trust their calculations because they cannot verify it by comparing with a "correct solution". They are challenged in the course to develop a more mature, relativistic [4] view on technology and engineering. In the open-ended advanced projects, there is seldom one single "right" solution with a single "correct" answer. It is not even sure there is an answer to be found with reasonable resources, or there may be several answers, more or less complete and applicable, depending on how one chooses to pose the question.

A majority of the students show increased confidence in their knowledge and capability during the course, sometimes after a shaky beginning:

– "*We made strength calculations in the beginning of the course and we concluded things that turned out to be correct when we tested the prototype. But at the time of the calculations, we didn't have much confidence in ourselves and our reliability. This made our ideas more or less rejected by the guys, because their calculations seemed much more serious, using [software] and everything. What I have learned from that is that I must be more confident. Just because you haven't used a fancy method, it doesn't mean that it is wrong*."

Decision-Making

While it is seldom possible to calculate a straight correct answer, still the technical work must lead to practical decisions. There comes a time when the calculations must be put aside and a decision be made, informed but not perfectly determined by the calculations. This is obvious in real design processes but not common in educational situations. This is a situation likely to be novel and almost traumatic for most students. An extreme example is the student who half-way through the course expressed severe disappointment over the limitations of theoretical calculations, and blamed the teachers for not reducing the problem to something perfectly solvable:

– "*Not that these were the only calculations needed, but the only ones that could be made based on experience. All the calculations assuming kinematic equilibrium seem to give various degrees of unreasonable results. This is not just a pity and shame, but it is also terribly bad pedagogy now towards the end of an education. I had really wanted it to be possible to use the theory that we have learnt. We cannot even calculate the strength since everything is so tiny*."

One of the main challenges to the students, and the reason why it is important that their views on knowledge is developed, is that it is virtually impossible to acquire and appreciate knowledge that doesn't look and feel like you think knowledge should. A student who expects and values "truths" will just see the world in black-and-white, looking for "truths". A few students fail to develop their view on knowledge and engineering in the way that is intended. An extreme case is this student who dismisses the application of technical knowledge altogether, as the calculations did not give the exact answers he expected:

– *"We could probably accomplish this project without any of our technical courses. We did a lot of calculations in the beginning, but they were very approximate."*

Recognising and Appreciating the Technical Knowledge

Some students have difficulty recognising and appreciating the learning of technical knowledge in this course. Many of the previous courses in the engineering education focus on learning already known and established relations and methods. In this course the generic skills to develop knowledge are trained and the learning is experience-based. The focus on synthesis, consolidation and application of also quite fundamental technical knowledge differs from the way students have previously seen knowledge being evaluated, for instance in exams. They do not initially realise how difficult it can be to integrate knowledge and apply it to an open-ended problem.

An insightful quote from a student who deeply understood this aspect:

– "*A lot of [my team mates] feel that we haven't used much of the knowledge from previous courses, because it doesn't look like exam tasks, it's not extremely difficult. But you have to think in broader concepts. We are supposed to put together this vehicle in different parts, and some view it as simple carpentry. But I see it as pretty*

advanced assembly of subcomponents, because you have to think about these parts are supposed to work together? And then, in the manufacturing process [...] It is a bit like tying knots. Here we tie simple knots, but we apply them in difficult situations. In previous courses we tied lots of advanced knots but we never applied them at all."

In the beginning of the course, the students formulate their personal learning goals. Many show expectations to attain goals related to advanced analytical or numerical analysis. We suspect that these goals are formulated using the view on knowledge acquired in previous disciplinary courses, and they do not know that a course like this accentuates another type of challenges and required knowledge, or they do not appreciate the sophistication of application and synthesis. Even towards the end of the course they sometimes fail to see that their original goals were perhaps unrealistic considering the nature of the course:

- *"My expectations on how much theory I was going to learn were not fulfilled*. *I can only speculate on the reasons for this. One explanation could be that very few theoretical lectures were given. This is not the whole truth, because I am also responsible to actively seek knowledge on my own. I can't really say why I haven't done that to the extent that I should.*"
- "*I had to give in on my goal of deeper knowledge within at least one technical area*, *in favour of my other goals that have dominated more than I imagined when I formulated them*."

What we want to achieve is that students change their views during the course, and appreciate the value of what they have learned:

- "*[My friend] said he didn't learn much technical knowledge. He said 'I didn't learn a thing!' But then when we started discussing, it turned out that there is actually a whole lot that we have learned*."

The Distinction Between Project Goals and Course Goals

Generally, the students focus solely on meeting the technical specification of the project itself, and don't reflect much on the learning. The distinction between reaching the project goals (building a product that flies or floats as required) and meeting the course goals (learning outcomes) does not seem to be clear to the students.

Is project success necessary, beneficial, convenient or simply unimportant? The answer is that it depends on how the issue is perceived by the students. It is thereby an important task for the teachers to constantly discuss the meaning of quality. If not discussed, project success is necessary for the students' self esteem and satisfaction. If properly addressed, project success is not as important since it is not perceived as the only indicator of a successful course and learning experience.

Perhaps the reason why students focus so much on the project is that the learning outcomes are simply not perceived to be as attractive as the design-build adventure is in itself:

- "*The focus of the majority is on the [vehicle]. A concrete technical goal, and you learn things around that, like positive side effects. A lot of us have said that for instance the feedback exercise was interesting. But if you promote a course and saying that you will learn about communication and things, it will not attract as many students as*

if you say we will build an [vehicle] that will be extremely cool and receive a lot of attention."

This quote illustrates two things. First, on the positive side, that the course succeeds in attracting and motivating students to take part in a demanding learning exercise. Even if it was not the learning itself that attracted them, they are pleased with the outcome in the end. On the negative side, however, we must consider whether the appeal of the course is too laddish, and should be more gender-neutral.

What Versus How

The assessment procedure described above might be mistaken for a "ready-to-use recipe". It should rather be viewed as list of good ingredients. From our experience very small differences in the implementation, presentation and even the timing of the different activities could totally alter the outcome or how the students receive the assessment exercises. For instance, a scheme quite similar to the one presented above was used in the previous year and did not come out by far as successful. At that time we put a lot of focus on the assessment system since we were anxious to show the students that we dealt with this seriously. We invited the students to contribute to, and comment on, the scheme we were planning to run and this turned out to startle them and give them the feeling that we were not in control of what we were doing. We eventually regained their confidence but it took a while to convince them that we were not "playing around" with their grades. We then learned that the presentation and implementation of the system is at least as important as the design of the system. One should also appreciate that we are asking the students to do quite difficult and demanding exercises and it is therefore crucial to maintain their confidence throughout the process.

In summary, the success of this kind of course activities is depending as much on how you do things as on what you are doing.

FINAL REMARKS

When you as a teacher transmit your vision of the course to the student group to gather their enthusiasm, and willingness to work hard and collaborate, you should show sensitivity and be attentive to the students' individual needs and capacities. For that end, among others, your mental presence is constantly required. Not only to observe, but first of all to interpret both their feedback and the situations that develop during the course. Constant involvement and control by the teacher is not necessary but the awareness of the teacher is.

It is finally important to understand that no student will ever come to the course and state a personal learning objective such as "I will try to develop a more mature view on knowledge". They simply do not miss the view on knowledge that they lack. Thus, when they later reflect on whether they attained their learning goals, they may need support to recognise and appreciate the learning outcomes they did achieve without having formulated them as personal goals.

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