Learning for Ill-Structured Problems in Engineering Education

Kristian Stålne and Delphine Bard

***Abstract*—An important goal of the engineering educations is to prepare the students to deal with complex and ill-structured problems. The term ill-structured refers to problems without conclusive or unambiguously defined solutions. This view on problems is related to the concept of constructive alignment and to an educational model called 6 languages for knowledge and learning that describe 6 increasingly complex perspectives, where the shift from the 3rd to the 4th perspective illustrates a shift from promoting well-structured and an instrumental view on learning to emphasizing ill-structured problems and a focus on the process in which the learner constructs knowledge. The model was used as a scaffold for constructing the course syllabus and learning outcomes for the teachers and for the students. The part of the course that could be framed as an ill-structured problem was the assignment. The process of engaging in the assignment was supported by a guide for teaching critical thinking.**

***Index Terms*—Ill-structured problems, perspectives on understanding and learning, constructive alignment, support.**

I. Introduction

One of the challenges of engineering education is to prepare the students for a complex and unknown world where one is faced with ill-structured problems, such that lack conclusive or definitive solutions [1]. An ill-structured problem typically entails dealing with uncertainties [2], that a number of different strategies or perspectives need to be employed, that the question or problem itself may not be clearly defined and that there may be several possible solutions or solutions that in turn give rise to new problems.

But how can an engineering program or course support such learning? How should the course content, teaching methods, examination and intended learning outcomes, generally referred to as constructive alignment according to John Biggs and Cathrine Tang [3], be designed in order to train the students to address ill-structured problems. The concept constructive alignment indicates that the different parts of the course and the student's activities should be consistent with each other, but not which underlying view or perspective on teaching that it should be based on. And how could we formulate an intended learning outcome if there is no clearly defined solution to the problem?

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II. Educational model

An educational model that addresses these questions is called 6 languages for knowledge and learning, developed by Erik Jan van Rossum and Rebecca Hamer [4]. It was inspired by Ference Marton and Roger Säljö's phenomenographic research and from adult development theorists such as William Perry, Marcia Baxter Magolda and not least Robert Kegan.

The model describes six qualitatively different perspectives on what it means to understand something, and what characterizes good teaching: *1. Increase of knowledge* and *2. Memorising*, the least complex and developed perspectives, based on an absolute and concrete view of knowledge; *3. (Reproductive) Application* specifies an instrumental view of knowledge and formulas as tools to solve well-structured problems; *4. Learning to think (as an expert)* emphasizes the knowledge of the process for handling ill-structured problems; *5. Multiple perspective / Relativism* is the ability to construct multiple perspectives on an issue, such as ethics, sustainability or social perspectives; *6. Growing awareness of self / Identity* describes a shift in focus from knowledge, perspectives or abilities to identity [5]. The 6 perspectives are further described in appendix.

III. Applying the model in an acoustics course

In order to promote students' abilities to engage in ill-structured problems as described in above, the model by van Rossum and Hamer was used as a scaffold for planning and implementing the course Acoustics VTAF05 at the Masters level at the V-program in 2013 and 2014. At the beginning of the course the students' own view of knowledge and learning was evaluated, which indicated that perspective *3 (Reproductive) Application* was the prevalent one, the one that emphasized an instrumental view on knowledge and solving well-defined problems. This result was communicated to the students on a group level along with an introduction of the educational model in the beginning of the course. The different parts of the course were then divided based on which perspectives that was reflected in the content, learning method and examination:

- Introduction of the basic concepts that were examined by written examination – perspective 2 and 3.
- Laboratory exercises that trained the students to solve well-structured problems that were examined by writing laboratory reports – perspective 3.
- A project assignment where the students had to address an ill-structured problem – perspective 4.

The first two parts were not introduced in any specific way since this is the most commons ways to perform teaching. The third part, the open and ill-structured project assignment was thus that part of the course related to the problem described in the introduction.

Introducing the assignment

The assignments were introduced in the middle of the course with quite brief descriptions. There were several alternative assignments for the students to choose from. Here follows two examples of project descriptions:

> "Design a multi-purpose hall for an audience of 200 persons. The hall is primarily intended for lecturing but shall also be used for acoustic music (chamber music, jazz)."

> "Most calculation methods on sound isolation in walls focus on monolithic elements, i.e. single leaf walls. Here the assignment is to produce a tool for estimating the transmission loss for different configurations and will be tested against some of the numerical models that are used in current research at the acoustic department."

In both cases some more details were given, but the assignments were explicitly stated to be open and ill-structured that allowed for finding own solution and then presenting and arguing for their choice. The work was presented by means of a written report as well as with a 5-minute movie that the students produced using their smartphone cameras and Windows Moviemaker.

We introduced the task orally with the support of writing short descriptions in order to guide the students through their common first apprehension of not be able to solving the problem and not knowing where to start. In this phase communication between students and teacher was initiated in order to guide the students in the "critical thinking process", in which they typically aim to further define and clarify goals of the analysis.

Support during the process

During the process of working with the assignment, which lasted for a few weeks, the teachers were present physically to answer any engineering related questions. But also, a significant part of the support (perhaps the most important regarding self-development) was also to guide the students through the analytic evaluation of the problem by having them questioning their own choices when so was needed and also by encouraging new and creative ways of approaching the tasks. Or using new technologies in a creative way, such as the use of digital resources.

In order to guide them and show that there are several ways to solve the problem, we introduced some concepts of reasoning and reflection, such as to recognize and control for own bias, to be explicit with on which assumptions they base their analysis and how to build consistent argumentations from these. This year we used a guide for teaching critical thinking called Steps for Better Thinking by Susan Wolcott [6] as a support to us teachers as well as to the students. This along with the model by van Rossum and Hamer were also used as support in formulating and communicating examination criteria.

IV. Concluding remarks

Although we haven't yet made any formalized course evaluation or evaluated results on the different grades, our impressions are that both models or tools was very useful in clarifying to ourselves as well as to the students what we expect and how we view the assignment. The model 6 languages to knowledge and learning was useful for understanding the prevailing perspectives of the students, perspective 3, which also would reflect their expectations on the course, and for making the students understand perspective 4 and introducing the concept of ill-structured problems. The other model, Steps for Better Thinking, was applied on a more operative level to guide the students in their respective processes.

Engaging in how to support students' abilities to deal with ill-structured problems is an ill-structured problem itself. This should therefore, of course, be seen as a work in progress. We will further develop and evaluate our course and our teaching in order to do so, and also hope for fruitful discussions and an exchange of methods and experiences among the faculty's teachers and pedagogic developers on these matters.

Appendix

Here follows a brief description of the 6 perspectives or languages from van Rossum and Hamer's model.

1. Increase of knowledge. A view of knowledge and learning that is about having and adding facts. Understanding according to this perspective is simply to know many things. Knowledge is either true or false, which is verified by comparing with reality. The view of good teaching is based on the teacher as an authority that in a purely one-way communication process conveys information to the passive student.

2. Memorising. This perspective has much in common with the first approach, the teacher is still the authority and the expert who conveys true knowledge to the slightly more active student. Here the student's focus has shifted from knowing to reproducing and performing and can thus structure the material in the more and less important elements, which is governed by the question "Will this come in the test / exam?"

3. (Reproductive) Application. In this third view of knowledge the main focus is on how the knowledge is applied, for example in a future profession or in life. Learning is therefore very much to practice, often in settings that are as close to reality as possible. Knowledge content consists thus often of strategies, checklists and cookbook recipes to deal with a number of known, well-defined and well-structured problems.

4. Learning to think (like an expert). The main difference from the previous approach is here that knowledge is meant to be applied to new areas, to ill-defined problems and that the knowledge construction process is seen more as a

process. Understanding means to independently find patterns and relationships and be able to relate with them to other areas and with what you already know. Here, knowledge itself is not the main goal, but for the student to acquire the ability to independently investigate, build and apply an understanding of any subject areas.

5. Relativism or multi-perspective. From the fifth vision emphasizes the ability to step out of the system or discipline according to the previous perspective. Typically, this view emphasizes the multiplicity of perspectives where each perspective gives rise to an argument and a coherent worldview. Therefore, the mutual contact, dialogue and exchange of ideas and perspectives is seen as increasingly important.

6. Growing awareness of oneself / Identity. From this view, one can say that teaching is about discovering and defining oneself. A shift in focus from epistemology to ontology. Here methods and techniques are not central, but not unimportant since they can be adapted to the situation and the classroom climate. Knowledge and worldview typically stress the paradoxical and seemingly contradictory as something to be embraced.

An introduction to the model in Swedish is available at http://komplexitet.se/lashornan/sex-sprak-for-kunskap-och-larande/

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