ASSESSMENT OF PROFESSIONAL ENGINEERING SKILLS - DEFINE, MONITOR and ASSESS

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ABSTRACT

The comprehensive pedagogical approach of CDIO is designed to meet the current and future requirements for engineering education. CDIO integrates the disciplinary technical knowledge and the professional engineering skills required in order to operate as an engineer in industry. Accordingly, professional engineering skills need to be included in the syllabus of engineering courses and study programs, which in turn call for the implementation of learning objectives, teaching activities as well as methods for assessing the professional performance of the engineering students. The implicit and intangible characteristics of professional skills, in comparison to the traditional disciplinary technical knowledge, require teaching activities, as well as assessment methods, that adapt to the nature and learning processes of these skills. Besides, university professors do not always have profound real life experience from industry and consequently, they might have limited knowledge about professional skills which of course delimits their ability to evaluate the students' professional performance. The objective of this study is to design and test a method to assess professional skills in an engineering teaching context. A suggested approach, based on the three consecutive steps of Define – Monitor – Assess, was applied and tested in an engineering course in which the students and professional engineers from industry interacted in an extensive role play simulation. The students' were actively involved in the three steps of defining the professional skills criteria, monitoring and documenting their professional performance on basis of direct feedback from the professional engineers and finally, assessing their learning process. The study concludes that the suggested approach is applicable in the assessment of professional skills with reference to a good alignment between the teaching activity of role playing and the assessment, the formative feedback from professional engineers monitoring the learning process and the realistic context provided by the location of the role play at the office premises of the respective professional engineers involved in the course.

KEYWORDS

Active learning, assessment, role-play, professional skills, industry participation

INTRODUCTION

The industry needs to hire graduated engineers with thorough knowledge in science, engineering principles and a general understanding of the complex products, processes, and systems that constitute the society of today. Graduated engineers are expected to quickly adapt to the market requirements and expectations of industry in order to become operational and professional engineers. In recent years, industry has experienced that graduated engineers show deficient abilities required in real-world engineering situations, despite having sufficient scientific and technical knowledge in engineering, e.g. [1] and [2]. Thus, besides the disciplinary knowledge needed, practice of professional engineering also requires the ability to work in teams with people of different professional and cultural backgrounds, to communicate orally and in writing, to understand the basics of markets and business processes, to be creative and innovative, to conduct to professional ethics and social responsibilities, and to understand the nature of engineering products, processes and systems [3]. In order to meet the industry requirements, engineering education programs need to include personal, interpersonal and professional skills in their syllabus with a retained scope on disciplinary technical knowledge.

The comprehensive pedagogical approach of CDIO is one initiative, among others, which is designed to meet the current and future requirements for engineering education. According to CDIO, the need for engineering education is "to educate students to understand how to conceive – design – implement – operate complex value-added engineering products, processes, and systems in a modern, team-based environment" [3]. The teaching context of conceiving, designing, implementing, and operating represents the professional role of engineers and provides hands on actions, integration of different subjects and a realistic setting in which to teach professional engineering skills and attitudes [3]. Thus, CDIO integrates the disciplinary technical knowledge and the personal, interpersonal, and professional engineering skills required. The approach of CDIO is in accordance to Dewey's [4] idea of activating the students in the learning process and Kolb´s [5] notion that a realistic and meaningful context will support the learning process. Further, Lave and Wenger [6] claim that a realistic learning situation and setting will foster the transfer of knowledge and skills from a university to an industry context.

Problem Statement

Adding professional, personal and interpersonal skills to the learning objectives of existing engineering programs and courses must be done, however, without reducing the existing curriculum of technical disciplines. Besides, the implementation of new learning objectives requires corresponding teaching and learning activities as well as related assessment methods. CDIO suggests active and experiential learning activities that include realistic design-implement projects [3]. Andersson and Hammar Andersson [7] and [8], among others, explore teaching and learning activities based on industry participation in realistic role play simulations as a means to support the learning of professional skills.

In the conception of Constructive Alignment, Biggs [9] explains the fundamental principal for course design in which the learning objectives of a course, the teaching and learning activities as well as the assessment method should be aligned. Accordingly, referring to the call for the implementation of professional, personal and interpersonal skills in engineering teaching, the first step of a curriculum update and defining the learning objectives should be followed by designing teaching activities that will support the students' learning processes and finally, finding assessment methods that can monitor the learning achieved by the students.

The kind of implicit and intangible nature and characteristics of professional, personal and interpersonal skills are genuinely different from the traditional disciplinary technical knowledge, and consequently requires a different set of teaching activities as well as assessment methods. Besides, university professors, despite being experts in their respective field subject fields, do not always have profound experience and knowledge about professional, personal and interpersonal skills.

Purpose, Objective and Delimitations

The general purpose of this study is to facilitate the teaching and assessment of professional skills. The objective is to design and test a method to assess professional skills in engineering education. The assessment method in this case study course is aligned to the teaching activities of an extensive role play simulation in which students play the role of engineers who interact with professionals from the industry in an industrial environment. The underlying argument for this teaching approach is to establish a realistic learning environment that challenges and motivates the students and, consequently, fosters the learning of professional skills. The study focuses on the teaching and assessment of professional skill, and does not explicitly include personal and interpersonal skills.

ABOUT PROFESSIONAL SKILLS

Teaching professional skills in engineering education involves considerations about learning and the development of competences among students, e.g. how the choice of teaching methods create the context in which the engineering students learn and how the teaching design interrelates and facilitates the learning of professional skills. Other issues to considered are the nature of professional skills and competences in the field of engineering and how these skills develop [10] and, further, how to assess and grade the students' professional skills. The CDIO initiative deals with those issues and particularly accentuates the importance of developing professional skills in engineering education [3].

Being successful in the development of engineers who can perform engineer work in real life situations and meet the expectations from different stakeholders in society include fostering the students to identify themselves as engineers during their university studies [10]. As stated by Christensen et. al. [11], development of engineering professional skills is very closely related to the formation of the identity of an engineer.

How to develop professional skills and competencies concurrently with the development of disciplinary knowledge is an important issue not only for engineering education, but for all study programs in higher education. To develop an understanding among the students of how to act within their specific profession, the culture and the ethical rules as well as understanding the consequences of one's actions are important parts of the professional development and understanding as well as the establishment of a professional identity. This will form the base of competences for the students in their field of profession. Bates [12] states that the concept of professionalism requires knowledge, autonomy, and responsibility to be integrated and interrelated in practice.

The development of competencies is a complex mental and personal process that involves many levels of knowledge [13], [14]. A competence can be described as consisting of knowledge, skills, and attitudes, as three interrelated elements [15]. A student must know what to do, how to do it, and understand the consequences of his or hers decisions wide perspective.

Accordingly, the teaching and assessment of professional skills in engineering education must make sure that all those elements are covered, practised and assessed during the course, and that the different elements are made explicitly clear and are explained to the students in terms of learning objectives and outcomes, teaching activities and assessment methods [9].

The assumption about learning as a social process which goes on in a certain context, leads to the next aspect with implication on fostering professional skills, namely that knowledge and understanding is dependent on the context in which it is learned. In education of professionals, the problem is often to transfer knowledge and skills learned in a university context into an industrial context. This is due to the situated nature of learning [6]. To be truly successful in educating the students, not only the disciplinary knowledge required, but also professional skills and attitudes, it is important to create a learning context which is as realistic as possible [9].

Clearly stated learning objectives are of importance in the teaching and learning of disciplinary knowledge as well as of professional skills. This stresses the importance, highlighted here, of being explicit to the student about what they are learning and why. The idea of alignment between learning objectives, the teaching methods and the assessment methods used [9] is also a powerful tool when fostering professional skills. Similar to the requirement of explicit teaching activities of the professional skills, the assessment methods should also be explicitly expressed as the assessment methods strongly influence the priorities and actions of the students [16].

ABOUT ROLE PLAY SIMULATION

This study deals with the assessment of professional skills in alignment with teaching and learning activity based on role play simulation in which students play the role of engineers who interact with professionals from the industry in an industrial environment. The underlying argument for this approach is to establish a realistic learning environment that challenges and motivates the students and, consequently, fosters the learning of professional skills. Literature reports on a variety of different role playing procedures and concepts applied for educational purposes in many different sciences and subject fields, e.g. social sciences [17], supply-chain management and marketing [19], natural resource management [20], [21], and accounting [22].

Many cases describe various advantages of role play. Maier et. al. [24] points out the values of role playing as a teaching method when it comes to developing personal and interpersonal skills by referring to how the students gained an improved understanding and control of emotions and feelings. They also improved their self-knowledge, and understanding of their attitudes and of human interaction in social situations. Craig and Amernic [23] describe role playing as “one particular type of simulation that focuses attention to the interaction of people with one another” and, consequently, they share the view that interpersonal skills are central to role playing.

The pedagogical concept of role playing as described in this paper rests upon the principle argument of establishing a realistic context, i.e. a realistic learning environment for the students. This argument stresses the importance of establishing a teaching context which is in accordance with the first, out of a total of 12, standards of CDIO. This argument is also supported by Pepper and Clements [25] who identify and describe the need to prepare students for the ever-changing and dynamic environment of engineering work and, in order to facilitate the teaching and learning of professional skills, they introduce the approach of role playing as a way to establish a realistic learning environment.

The teaching method of role playing also supports the understanding of the underlying context, the functions of the different actors involved and the complex dynamic nature of the given problem [21]. The establishment of realistic environments and scenarios for the role play encourage the participant to become involved in, and commit to, the learning process [26]. Besides the immediate purpose of generally improved learning from role playing, the active involvement required in role play simulation promotes an enhanced enthusiasm, motivation, and a positive attitude to the teaching subject [22], [27], [23].

Even though role play has many documented advantages, literature also reports on challenges using role playing as a teaching method, both from the participants´ and the teachers' point of view. Craig and Amernic [23] bring forward the risk that the roles played by the participants can emphasize stereotypes and maintain prevailing, and inadequate, behaviour and relations. On the other hand, to a certain extent the given roles to be played need to be of a stereotyped nature in order to be distinct and familiar to the participants [27]. The value of enhanced commitment and enthusiasm among the role play participants must also be balanced in order not to turn the role play into a too frivolous and giggly game where the learning process is neglected. If the value and the procedures of the role play concept is properly conveyed and perceived by the participants, the "constructive peer pressure seems likely to operate to prevent role play degenerating into play" [23]. Participants with no previous experience from simulations might express an initial anxiety and apprehension about acting and performing in the role play situation [28], and as a consequence, they may adopt a cautious and non-committal attitude or even withdraw from the course [26].

METHOD

The assessment method of professional skills, designed and reviewed in this context, rests upon a case study of an engineering course at the Department of Management Engineering, at the Technical University of Denmark, DTU. The test and empirical data collection were carried out in the spring semester of 2012. The subject of the case study course was Building Information Modeling used for construction management purposes. The teaching was project based, the course was optional for students in the final year of their engineering program, the course credits corresponded to about 35% of full-time studies for a semester, there was about 20 students from different engineering programs and nationalities in the class, the students worked in groups of about three students, and the groups are formed by the teacher. Civil-engineering students constituted the main target group of the course, primarily supplemented by students from the architectural engineering program.

The assessment approach reviewed in this study was designed in close collaboration between the two authors of the paper, i.e. the teacher in charge of the course and a pedagogical expert from the pedagogical support centre of the university (the LearningLab). The follow-up and critical review of the applicability and results of the assessment method were based on empirical data collected from the students of the course and the professional engineers who actively participated in the role play together with the students. The data collection included the written preparatory documentation provided by the students, minutes from the role play meetings with the students and the professional engineers, a questionnaire carried out at the start and at the end of the course, and the students' written personal reflections about their individual learning progressing regarding professional skills. Besides, continuous discussions with the professional engineers during the course and a concluding group interview provided valuable input for the review of the assessment approach.

EXTENDED ROLE PLAY WITH INDUSTRY PARTICIPATION – THE CASE STUDY

The teaching and learning activities of the engineering course in this case study were designed as an extensive role play simulation in which groups of three or four students carry out a project assignment in the role of construction managers, assigned by a professional client from industry. The project process and the role play provide the corner-stone of the course, facilitated by input from the so called teaching process that consists of traditional lectures and exercises. Relevant theories and methods were introduced on basis of the discussions and requests raised by the professional clients in the role play.

The project assignment and the role play run throughout the 13 weeks of the course. On the very first day of the course, each group of students were invited to a business meeting by their respective professional client. The role of the client was played by a professional engineer, typically employed at a consultancy firm or a contractor. The respective student teams organised themselves as fictitious consultancy companies with a company name, a logo and a business plan etc. in order to prepare for the first meeting. This initial work prepared the students in the roles of engineering consultants, it introduced them to the general terms and conditions of the subject field and, not least, the teambuilding process in the groups got started.

The meetings between the students and their clients took place at the office of the respective industry representatives in order to strongly contribute to the realism of the project assignments. The students were responsible for setting up the meeting appointments with their respective client, to agree on when and where to meet, to prepare a meeting agenda and to keep the minutes of the meeting.

The recurrent project meetings with the clients made up milestones during the course, i.e. as project phases at which the students reported and discussed their intermediate results. It was the clients who pulled the project process forward in dialogue with the students. Consequently, the clients successively expressed new requirements for the project assignment which, in turn, created a need for new disciplinary knowledge among the students. Thus, when the students returned to the teaching process of the course, they had an explicit urge to learn the disciplinary subjects in order to deliver an answer and solution to their client at the next meeting.

Andersson and Hammar Andersson [7] discuss in further details the pedagogical aspects of teaching by role playing simulation with industry involvement and how it relates and supports the learning of professional skills.

ASSESSMENT OF PROFESSIONAL SKILLS – THE CASE STUDY

Andersson and Hammar Andersson [7] reported on a genuinely positive attitude towards the role play simulation with industry representatives among the students of the course. Actually, the interaction with the industry professionals was highlighted as the most positive aspect of the course in the case study. The role play simulation with industry participation provided unique possibilities to deal with some of the most obvious challenges related to the assessment of professional skills in engineering teaching. For example, the nature and characteristics of professional skills are implicit and intangible compared to traditional technological knowledge [29] and professional skills must be considered and understood in relation to the given context in which the professional skills are performed [6]. Besides, professional engineers know about

processional skills on basis of their own experience from industry and, consequently, they ought to be capable of assessing the students' professional performance.

In order to meet these challenges, an approach to the assessment of professional skills, consisting of three steps, was designed and tested in this study:

Step 1: Define – Identification of relevant aspects of professional skills
Step 2: Monitor – Continuously monitor and document the professional skills
Step 3: Assess – Reflect and report on the learning progression of professional skills

These three steps will be described in closer details in the following paragraphs.

Step 1: Define – Identification of Relevant Aspects of Professional Skills

The first step of the assessment method included an introduction to, and a definition of the concept of professional skills in an engineering context. On basis of this introduction, the teams of students identified aspects of professional skills that were of relevance for them in the given situation, i.e. the project assignment of the course and the role play interaction with industry representatives. Examples of professional aspects identified by the students in the case study course included the "ability to listen", "roles and responsibilities", "representing the company", "preparation", "reliability", "argumentation" etc.

A basic implication of the first step was simply to make the students aware of the learning objectives related to professional skills, i.e. to make the learning of professional skills an explicit and tangible part of the course. Step 1 correlates to the development of competences described e.g. by [13], [14] and [15].

Step 2: Monitor – Continuously Monitor and Document the Professional Skills

The monitoring process was represented by the feedback, discussion and documentation of the students' professional performance that took place in the role play simulation in which the students interacted with their respective "client", i.e. a professional engineer. In the engineering course described in this case study, the students arranged meetings with their clients and performed the role play simulation about four or five times during the thirteen week course period. Each meeting with the student groups and their respective clients lasted about one to two hours. When the meeting and the role play simulation were concluded, the professional engineer provided an immediate review and feedback to the students about their professional performance. Besides, at every meeting, one student was assigned to the role of an observer being responsible for monitoring and documenting the professional performance of the students following the list of identified aspects prepare in step 1. The client's feedback, the observer's notes and relevant topics from the review and discussion were documented in an observer's protocol.

The instant feedback from the professional engineer to its group of students that took place in this course was a typical example of a formative assessment, which normally includes qualitative feedback on the content and performance. Formative assessment took place repeatedly during the course, i.e. during the learning process, in order to successively enhance the students' skills [30], [31]. Literature reports on a number of benefits related to formative assessment, e.g. to facilitate the students' self-assessment and awareness of their own learning process [32], to identify and to deal with shortcomings in the group or individual performance [33] and to encourage a peer dialogue about learning [34].

Besides, in this case study the teaching activity as well as the assessment of the professional skills took place in the natural context and surroundings of professional engineering work, i.e. in the office premises of the respective professional engineers involved in the role play which helped to enhance the aspects of situated learning while reducing the problems of knowledge transfer [6].

Step 3: Assess – Reflect and Report on the Learning Progression of Professional Skills

In the concluding assessment of step 3, the students reflected upon their own learning process from the initial step 1 to the formative assessment in step 2. Thus, step 3 constituted an individual self-assessment of the professional skills achieved which were described together with personal thoughts and considerations about the learning process. The assessment was documented in writing on a single page and was handed in by each student together with the documentation from step 1 and 2. The individual reflection of step 3 was designed to help the students to become conscious about the professional skills they posses and how their engineering identity developed during the course, which in turn will support the learning process [11], [9].

It was manifested from the self-assessments handed in by the students in the case study course that there was a generally positive attitude towards the role play simulation among the students and that the interaction with industry professionals supported the learning of professional skills. The following quotes provide some examples from the students' self-assessments of the case study course:

"The knowledge gained from overcoming the challenges in a professional setting are not typically learned in a classroom. I have newfound respect for myself, and my team members on what we have accomplished under the given situation."

"Finally, the experience of working so closely with the employees XX, YY and ZZ has been awe-inspiring. It has truly driven me to reassess my place in the construction industry and the direction I would like to take with my future studies."

"Now, I understand that a balanced combination of engineering knowledge and interpersonal skills initiates a development of true "professional skills". Identification and reduction of social risks within the group, clear presentation of ideas, commitment or time management are only a few terms, which I started to look at from a different perspective."

"I think that the role-playing aspect of this course has helped me a lot. I have learnt to be more responsible and to represent my company and its interests."

"I had to listen to what the client was asking of me and their suggestions so that what I produced was relevant to their wishes."

"This means that the course hasn't been my first opportunity to gain professional experience. I though find it very exciting that the course had this part included, and I have for sure learned from it".

"... where we appeared very young and inexperienced at the first meeting, I feel that our client in the end started to have some respect for what we were doing".

There were of course some, but only a limited number, of negative remarks in the students' personal comments. Those remarks typically referred to e.g. *"the buggy software that lead to a lot of frustration"*, *"the time to practice the software was limited"* and similar remarks which did not relate to the role playing or the learning of professional skills. However, when considering the limited number of negative comments and when validating the results of the individual self-assessment it is important to know that the self-assessments were handed in before the students had received their final grades. This can of course delimit their willingness to present and hand in negative remarks to their teacher about their learning process and the course in general. Handing in the individual self-assessments was a mandatory part of the examination. However, the self-assessment was not included in the grading of the students, i.e. the self-assessment can only be given the grades of approved or not approved, where the latter option was only effective if the student failed to hand in the self-assessment.

Finally, there were fundamentally different ways to approach the self-assessment in the group of students and consequently, in order to get more precise answers, to make comparative analysis of the results and to get more accurate picture of the learning achieved, the guidance and instructions must be made more detailed and standardised. The comments that were handed in did not only include the students' reflections about professional skills, which was presented as the main objective, but also included general comments about the course, the subject and other matters of concern.

CONCLUSION

This study adds to the discussion about learning and assessment of professional skills in engineering education. A simple approach to the assessment of professional skills, based on the three consecutive steps of Define – Monitor – Assess, was designed and tested in an engineering course in which a role play simulation with industry participation provided the central teaching activity.

It was concluded, on basis of the written and oral information provided by students as well as the professional engineers involved, that the suggested approach was applicable in the assessment of professional skills. The viability of the assessment approach rests upon three cornerstones of:

- a good alignment between the teaching activity of role playing and the method of assessment, which allow the students to actually practice their professional performance
- industry involvement, i.e. the formative assessment in which professional engineers, with solid experience from industry, provide instant feedback to the students about their professional performance.
- the realistic context, i.e. the role play was located in the meeting facilities at the office premises of the respective professional engineers, which contributed to the professional dimension, enhanced awareness and to the learning process of professional skills in the course.

The approach showed some minor weaknesses in step 3, i.e. the concluding self-assessment, in which the students were asked to personally reflect upon their learning process in terms of a self-assessment. The written assessments handed in turned out to be quite disparate in terms of content, scope as well as the layout. The students' comments did not only cover the topic of professional skills, but also remarks and evaluations of the course in general. Thus, the purpose of the self-assessment need to be more clearly stated and supplemented with more precise guidelines in order to get more unambiguous forms of assessments, if that is desirable...?

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