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'Pan-Mentoring' as an Effective Element of Capstone Design Courses*

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Because of the ambiguous nature of the capstone design course between the perfect setting for problem-based learning (PBL) and the unique challenges of the design process and its outcome, the third component of the PBL triad 'problem/student/teacher' gains additional importance, i.e. the teacher. This paper explores the role of the teacher in a capstone design course as a 'pan-mentor'. 'Pan-mentoring' is defined here as establishing a close relationship with teams of students during the capstone design project, in order to foster the students' learning and to ensure a satisfying project outcome. Thus, 'pan-mentoring' addresses challenges of capstone design (the chasm between theory and practice, vagueness and open-endedness, and performance anxiety) by drawing on the advantages of PBL (such as, self-regulated learning, enhanced critical thinking, and increased creativity).

INTRODUCTION

THIS PAPER explores the role of the 'pan-mentor' in the problem-based learning (PBL) triad of problem/student/teacher. By its very nature, the capstone design project implies already certain aspects of PBL as a learning/teaching method; obviously the starting point is a problem, and obviously the students learn how to solve it as they are working on the project. However, content and outcome play an important role in this course: often the projects are sponsored and expectations of success loom accordingly high. The vagueness and open-endedness inherent in the design process tend to confuse students and even block their creativity.

Here, the third component of the triad gains additional importance: the teacher. While generally the role of the teacher in PBL is described as facilitator, the particularity of capstone design requires a mentor. Since one is usually working with a small team of students instead of individual ones, I choose the term 'pan-mentoring' (a modification of the term mentoring that implies a one-on-one relationship) in order to include all members of a team of about three students working on the same project. 'Pan-mentoring' in the sense of establishing a close relationship with students without imposing methods, views, or solutions, can compensate for the special challenges of this phase which include:

- The gulf that still exists between theoretical knowledge acquired in previous classes and its application in a design project [1]. In my experience, frequent meetings with small teams monitoring the students' self-regulated learning, enable students to finally bridge the chasm in their own way and learning style—ideally leaving them with increased independence.
- The vagueness and open-endedness inherent in the design process often confuse students. Simon [2] regards the design process as a continual cycle of producing alternatives and testing to assess them, a process that students often find painfully difficult and that makes them desperate for a sounding board and other forms of help-generating alternatives.
- The high level of creativity needed in capstone design requires that students draw on a variety of brainstorming and idea generating activities and that they feel comfortable taking risks in spite of performance anxiety.

Thus, 'pan-mentoring' addresses challenges of capstone design (chasm between theory and practice, vagueness and open-endedness, and performance anxiety) by drawing on the advantages of PBL (such as, self-regulated learning, enhanced critical thinking, and increased creativity).

SELF-REGULATED LEARNING

In the project setting, one can focus on the individual's preferred learning strategies. Letting the students choose their own method of problem solving and giving them more responsibility motivates students especially at this level of their education. For example, in a team of students designing and constructing a head-impact sled jig, I encouraged them to fully pursue their own ideas. When the students presented their idea of how to accelerate the ATD-head to me, they were not sure whether a pulley mechanism or a drop-swing mechanism would be most effective. They

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were leaning towards the pulley mechanism but the lingering doubts made them very uncomfortable. After being reassured that for the time being uncertainty and lack of clarity were acceptable, each chose an aspect of the mechanism to research in more detail and later fitted their pieces together, deciding on the pulley mechanism. Their motivation increased since there was a feeling of ownership of the project.

This case reflects a constructivist approach to teaching/learning, emphasizing that the learners discover and thus construct knowledge. During the capstone phase, the students mainly need a 'pan-mentor', a mix between personal advisor and knowledgeable sounding board. Given an opportunity to meditate over a problem, the students are by now quite capable of creating solutions. As Li [3] points out, information technologies such as the World-Wide Web or shared databases assist students in the construction of knowledge. However, in this transition phase between school and 'the jungle out there', the students have a need for reassurance and positive feedback. After discussing their projects and receiving a knowledgeable feedback, they tend to take more risks and to produce more unusual ideas.

ENHANCED CRITICAL THINKING

The tasks of dealing with uncertainty, solving complex problems, and probing the unknown are best tackled through discovery-based learning experiences [4]. However, students are easily frustrated by the vagueness of the design process, and often consider the necessity of making changes as a failure. Here it is the pan-mentor's task to assure the students that the continual cycle of ideas, sketches, and modified ideas is in fact desirable, indeed part and parcel of the design process. Boeckh [5] describes this early designing phase as a complex manual sketching process that contrasts starkly with using computer-aided design (CAD) systems. Even though attempts are currently being made to bridge the gap between the hand sketches and CAD systems, such tools are not yet commercially available. As long as students think that the challenge of linking the many elements of a complex problem seems to be difficult just to them, they may doubt their own competence. Faced with open-ended problems, the students often feel as if they are groping in the dark. They experience the design work as a suite of generating ideas, testing them, noticing shortcomings, and modifying the original idea. As Simon [2] describes it, most of the effort and time is spent in creating the alternatives, which are not given at the beginning. The students need to be able not only to express their frustration, but also to hear that uncertainty and modifications are a normal part of the design activity.

Certain classroom assessment techniques provide feedback not just on teaching, but also on learning and even on the progress of designing. Any engineer (as a matter of fact, any person who deals with a complex problem) can profit from a device like the 'muddiest point' exercise [6]. A thinking tool like the 'muddiest point' helps to create awareness where the main problems or impediments of constructive thinking lie. The 'muddiest point' assessment enables students to clarify trouble spots, either in a lecture/information provided by the instructor or in their own learning experience. Angelo and Cross [6] label it as simplest classroom assessment technique imaginable, yet a 'remarkably efficient' one, because it requires very little time or effort. Students simply jot down what troubles or confuses them about a limited topic. Even though the 'muddiest point' exercise is meant to give the instructor a feedback, especially in large low division classes, it also works as a feedback for senior classes. Once they force themselves to pinpoint a trouble spot, they can focus on working on it. As Angelo and Cross [6] put it: this technique promotes introspection and self-assessment.

Another technique providing feedback, both for students and pan-mentors, is the 'minute paper' [6]. It resembles the 'muddiest point' technique in its briefness as well as in its effectiveness to help a learner clarify areas of concern. One can ask students to jot down what each judges to be the most important or the most difficult point of a given topic. An adaptation for small research teams during the capstone phase would be to ask students to summarize briefly in writing (minute paper) their own contributions to or their difficulties with the project since their last meeting. A written statement provides a starting point for group discussions and for peer assessment, including mutual help and teamwork. Most likely without a pan-mentor incentive, students would skip the step of expressing their thoughts in writing and thus miss out on a useful learning technique.

Peer-assessment in form of group discussions also works in several ways. It gives the pan-mentor not only an idea of what a particular individual learns and contributes to the project, but also illustrates the level of understanding of the assessor. Additionally, it helps the students to check their progress of work and learning, as they have to present both, their research and arguments in evaluating a peer's research. These group discussions should initially take place in the pan-mentor's presence, after which the students can proceed on their own. It is the pan-mentor's task to draw the students' attention to all of the above techniques.

INCREASED CREATIVITY

At the very beginning of the capstone design project, I encourage students to work just with pencil and paper, because 'thinking on paper' helps to establish some clarity. Researchers analyzing the designing process, including video taping forty-five mechanical engineering students and fifteen industrial designers, emphasize the 'necessary vagueness' (*notwendige Unschärfe*) of manual sketches created during the initial phases of product conception. They describe that the designer turns a vague sketch into shapes only very gradually in order to leave room for changes [5]. Without this encouragement, students tend to use high-tech equipment right away. However, researchers found that CAD systems could not emulate the wealth of information contained in the 'back of the envelope' sketches [5]. Furthermore it has been shown that CAD systems can actually hinder the creativity through the necessity of inputs of the artifact parameters, while the connection between the human brain and a hand-held a pencil leaves room for vagueness and changes, and thus can do the job more efficiently [5]. Consequently, the pan-mentor has to step beyond the role of facilitator and actively encourage students to try alternative creativity-generating methods.

While sketching represents a brainstorming activity on an individual basis, I encourage my students to practice collective brainstorming, too. Fink [7] observes that teamwork is an essential element in the learning process. Additionally, teamwork will also be an important factor in their professional future [8]. Team discussions work well especially during more advanced stages, when ideas need to be analyzed. Other techniques can also help to tap less conscious levels and to generate starter ideas. During the early brainstorming activities in a given team, I encourage students not to worry about the quality of an idea but rather generate a large quantity. Faste [9] explains a technique called 'ball games,' an improvisational drama device that he uses to put students into a creative mental state. Whoever the ball is thrown to, will spontaneously say what he/she associates with the word the pitcher said. After loosing their shyness, the students should be ready to pass just ideas within a group almost playfully, without fear of saying something wrong, thus really tapping a pool of collectively generated creativity. I have not yet tried this method myself, but Faste [9] makes it sound so promising that I plan on using it.

Eggen and Kauchak [10] emphasize the importance of the teacher to develop an atmosphere supportive of risk taking. To encourage risk taking I always make it a point that at the onset of brainstorming there is no such thing as a bad idea (I usually throw in a really weird example to open the flood gates, so to speak), and that *every* idea is welcome. Cohen [11], who views the role model function as an essential part of the mentoring relationship, regards the expression of a 'confidant's view of appropriate risk taking,' encouragement, and confidence in the mentee as particularly valuable outcomes of this function.

In addition, my students have to present five distinct ideas of tackling their capstone design project instead of letting them get by with just one suggestion. This requirement stretches their imagination beyond the obvious. At the same time, those ideas make a nice storage to feed in alternatives later in the design process. Psychologically, the mere presence of additional ideas can give the student a sense of control and confidence.

ASSESSMENT

Assessment of students can be a touchy topic in a pan-mentored class because assessment emphasizes power structures (the teacher gives grades, the student receive), which have been downplayed through the students' learning process [12]. Sluijsmans *et al.* [13], consequently demand that the characteristics of PBL need to be 'transferred to the design of assessment'. It is possible to use student assessments in the capstone design class in a way that emphasizes the characteristics of PBL (independent learning, construction of knowledge, solving complex and vague real-life problems) and emphasizes the role of the 'pan-mentor' as an adviser and facilitator in the learning process. I request real-life oriented writings to document the students' learning process: an initial proposal, a progress report and short presentation, and final report and presentation (which because of the group setting, includes peer evaluation).

Course assessment of a pan-mentored class, too, requires a consideration of the special circumstances. So far, I am relying on two types of assessment: the formal student evaluation as prepared by the University and the (admittedly unstructured) comments of my students and ex-students. Ideally, one would need an assessment tool inviting comments on student self-assessment, group-work evaluation (Angel and Cross [6] present a sample), and the pan-mentor's usefulness—not just in the problem-solving process, but also the pan-mentor's role in the learning process. Note the difficulty for students to fairly evaluate an instructor who helps them to search for an answer rather than give them the answer!

Consequently, the assessment of the pan-mentor is rather an introspective enterprise. Cohen [11] offers a useful metric list of fifty-five prompts, which he calls 'Principle of Adult Mentoring Scale—Post-secondary Education.' On a scale of five choices from 'never' to 'always' one can rate, for example, how often one shares personal examples or how often one engages students in 'discussions which require them to reflect on the new competences that they will need to achieve their future goals' and thus evaluate at least to some extent one's effectiveness as a pan-mentor.

CONCLUSION

In PBL, the teacher's position in the background implies one possible danger: to appear totally out of view of the students or not to appear available. Savin-Baden [12] speaks of the danger that facilitators might perceive students as so autonomous that they stop facilitating them. Consequently, the 'pan-mentor' should schedule frequent meeting, both to stress his/her availability and to function as a reassuring, encouraging knowledgeable sounding board, thus promoting self-regulated learning. This encourages students to take risks, seek information on their own, and explore ideas. To enhance critical thinking, the pan-mentor needs to assure that the continual cycle of ideas, sketches, and modified ideas is in fact desirable and typical for the design process. The pan-mentor needs to stress during visits with the students that uncertainty at this point does not mean incompetence. Also, the pan-mentor needs to draw the students' attention to techniques promoting introspection and self-assessment. To help students increase their creativity, the pan-mentor should encourage students to practice more than one type of brainstorming. Especially important is the task of fostering collective brainstorming.

I actively seek feedback from students in my senior classes and from those who have gone on to industry, and their responses have been positive and encouraging. The special challenges inherent in capstone design can, with an emphasis on PBL as both method and philosophy *and* an emphasis on the teacher's role as a pan-mentor, be turned into a satisfying learning experience, including an acceptable project outcome.

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