CAPSTONE BOOTCAMP CONCEPT CATALYZING PROBLEM-BASED LEARNING

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ABSTRACT

Changing from a traditional classroom and lecture-based teaching mode to a CDIO-based engineering education is not easy for either teachers or students, especially in a double-degree setting combining different kinds of cultural approaches. In this paper, we examined how students in a Double Master's Degree Programme between University of Turku, Finland and Fudan University, China adjusted to the change from traditional classroom lecturing to a coached peer-to-peer teaching. The change was supported by a teaching team and catalyzed with hands-on practices in a specifically designed intensive two-week Capstone introductory course - Capstone Bootcamp, which included one-week theoretical preparation and one-week hands-on workshop employing integrated learning and active learning. The course aimed to eliminate students' confusion about "Capstone", get them aligned in a new environment, and help them quickly find their roles when doing a Capstone project in the coming autumn semester with independent thinking ability. The initial analysis shows that the Capstone Bootcamp concept was able to increase students' understanding of problem-based learning approach, the advantages of reflective learning and active learning, and the importance of participatory teamwork in ambiguous and open-ended project settings with design thinking methods. In addition, we discussed the effect of teaching methods and the role of the learning atmosphere and environment to learning, and summarized the essential attributes for a Capstone introductory course as the future development of the Capstone Bootcamp at the end.

KEYWORDS

Problem-based Learning, Design Thinking, Capstone Project, CDIO Standards 1, 2, 3, 4, 7, 8, 11

1 INTRODUCTION

1.1 Background

The Capstone Bootcamp, including a week of theoretical preparation and a weeklong intensive workshop, served as an introductory course for a mandatory Capstone Project

Course. It was specifically designed as a part of a summer school for the 2-year Double Master's Degree Programme in ICT between University of Turku (UTU), Finland and Fudan University (FDU), China. Students in this Programme are required to study at their home university for three semesters and one semester exchange period at the host university. This cohort started at FDU spending the first two semesters there, after which they went to UTU for the third semester. The cohort consisted of 16 Chinese students altogether.

Planning process for the summer school and the exchange phase included both surveys and semi-structured interviews carried out for students and teachers. We discovered that the students had concerns regarding living and study environment, language problems, and knowledge of Capstone Projects. Especially the last-mentioned was a totally new concept for the students. For some students, conducting the project course was considered to be the most difficult part of their studies. This gave impetus to the summer school teaching team to plan a special introductory course - Capstone Bootcamp to the Capstone Project Course focusing on the learning methods, project management, teamwork, and communication skills, which are in the core of the Capstone Project Course's intended learning outcomes.

The Capstone Bootcamp started theoretical preparation in the third week after students' arrival to Finland, and held the hands-on part Workshop in the fourth week. It aimed to eliminate students' confusion about "Capstone", get them aligned in a new environment, and help them quickly find their roles when undertaking a Capstone Project with necessary non-technical skills in the coming autumn semester. The schedule of the Workshop and daily routines consisted of introductory lectures with discussion, prototyping, teamwork, and team building activities from dawn to dusk. Students gave group and individual presentations, and performed peer assessment. All the students' activities and presentations were assessed by teachers as well. The Workshop culminated in a final task - "Designing Your Own Capstone Project Course" which integrated the learning outcomes of the week. The Workshop was held in Archipelago Research Institute of UTU, which is located in an isolated island in the middle of Finnish archipelago. This environment was also found influential as represented later in the paper.

1.2 Method

The research framework follows a case study structure and the analysis of the interviews was done using grounded theory method. Mixed methods included also observation and some quantitative examination concerning the students' learning outcomes. The data was gathered from both qualitative interviews and quantitative surveys. Semi-structured individual interviews and group interviews were conducted before and after the Capstone Bootcamp. All the 16 Chinese students from the Double Degree Programme participated in both the interviews and were part of the data set.

Individual interviews were conducted in June 2014 before students departed to Finland. It was more focused on students' personal study experience, learning status, expectations, and concerns about the coming study period in Finland. The students' feedback was an essential catalyst and motive for FDU to make targeted improvements on the summer school. The set-up of the Capstone Bootcamp is one of the corresponding measures.

Group interview was done within a week after the Capstone Bootcamp, aiming at evaluating students' learning outcomes and impact of the course. Compared with individual interview, group interview, in addition to the advantage of timesaving, can facilitate to elicit diversified responses (Cohen, Manion & Morrison, 2007). It allows the interviewees to "complement the

other with additional points, leading to a more complete and reliable record"; meanwhile it helps the interviewer to "detect how the participants support, influence, complement, agree and disagree with each other, and the relationships between them" (Arksey & Knight, 1999; Cohen, et al., p. 373). In this paper, all the quotations of students' comments are from the group interview.

2 THE CAPSTONE BOOTCAMP

2.1 Connection between Capstone Bootcamp and CDIO

The design of the Capstone Bootcamp followed the CDIO philosophy, reflected the CDIO standards (Crawley, Malmqvist, Östlund & Brodeur, 2007), and underlined the problem-based learning (PBL) approach. PBL is widely used as the learning approach in the CDIO engineering education structure and the combination is found both productive and mutually reinforcing (Edström & Kolmos, 2014).

The Capstone Bootcamp had a similar role as the *Introduction to Engineering* course in the CDIO curriculum (CDIO Standard 3, 4), provided the framework for a Capstone related knowledge, and introduced essential personal and interpersonal skills. The teaching team designed explicit intended learning outcomes (CDIO Standard 2) for this course, and each assignment set in the course had corresponding intended learning outcomes as well. Students were expected to master Capstone related terminologies; get used to the new teaching and learning methods such as hands-on, integrated, active, and reflective learning; understand intended learning outcomes, and the importance of non-technical skills (CDIO Sandard 1, 7, 8).

Learning assessments (CDIO Standard 11) were done during and after each assignment. This was compatible with the objectives of the learning process in PBL (De Graaff & Kolmos, 2003). Peer assessment, as an arrangement for learners to consider and specify the level, value, or quality of other equal-status learners' deliveries (Topping, 2009), was applied to evaluate students' presentations with criteria and grading standards set by the teaching team. Teachers acted as a facilitator in the mutual learning process. The rationale was to promote learning (Boud, 1988), and support PBL in terms of constructive approach to learning as well as collaborative learning (Schuwirth & van der Vleuten, 2010).

The programs, intended learning outcomes and their connections with PBL principles and CDIO standards are listed in Table 1.

Table 1. Intended Learning Outcomes and Connections with PBL & CDIO
Based on De Graaff and Kolmos (2003); Lehmann, Christensen, Du, and Thrane, (2008).

Programs	**Intended Learning Outcomes (knowledge and competencies gained)**	**Connection with PBL Principles**	**Connection with CDIO Standards**
Reading and Context Research as Pre-assignments	Problem-solving, Contextual analysis (learning PBL, design thinking, reflective learning theories and Capstone related knowledge)	Cognitive learning/ Contents	Standard 1, 2, 8, 11
Prototyping: Egg Competition and Rope Test	Collaboration, Communication (personal and interpersonal skills), Project management and planning	Collaborative learning	Standard 2, 8
Strategy Lecture - Doing Technical Projects from Business Perspective	Subject knowledge, Technical skills, Cross-disciplinary knowledge, Knowledge management (product, process and system building skills)	Contents	Standard 2, 7, 11
Designing Your Own Capstone Project Course	All the above-mentioned mutually supported intended learning outcomes	All three principles above	Standard 1, 2, 3, 4, 7, 8, 11

2.2 Reading and Context Research as Pre-Assignments

Pre-assignment, including reading, evaluating, and preparing a presentation of 4 articles regarding design thinking, PBL, and prototyping, was given to students in the first week of the Capstone Bootcamp. The purpose of the pre-assignment was to familiarize students with the teaching approaches that the teaching team was going to use in the following intensive Workshop week. Students were divided into 4 groups. Each group got one different article for in-depth reading. They were asked to present the main idea and their own understanding of the article during the first Workshop day instead of only listening to lectures. What they learnt from the articles was all applied later to assignments. This active learning approach, often contrasted to the traditional lecture-based learning, is generally defined as an instructional method with the emphasis on student activity and engagement in the learning process (Prince, 2004; Goldberg, 2012).

The assignments were assessed by peers after each presentation. In addition to the advantages stated in 2.1, peer assessment ensured students to pay more attention to other groups' presentations and improve their own understanding through reflection. The assessment criteria, constructed by the teaching team, are shown in Table 2.

Table 2. Assessment Criteria

The criteria *were based on the following metrics (% means the weights of each area):*
1. Understanding the core ideas of the paper (45%): “I get what the paper is about".
2. Added value and constructive ideas with reflection (15%): “The team can build on and reflect from the paper – they have good comment, ideas and critique about the paper".
3. Level of understanding in the whole team (10%): “I can see that the whole team has really understood what the paper is about".
4. Easy to follow the presentation (visuality, communication & presentation style) (10%): “it is easy for me and other listeners to follow the presentation”.
5. Team effort (10%): “I can see that the whole team has worked hard”.
6. My own metric (10%): “There is something so special in this presentation that the 1 to 5 metric did not think of. That special thing is..."

2.3 Prototyping: Egg Competition and Rope Test

Egg competition was the first outdoor activity. Each student group was asked to design an egg carrier that could protect a raw egg when dropping from a 4-meter high lifter. They could only use the materials provided by the teaching team. To increase the challenge, in each group one student was blinded by covering his/her eyes, and one was deafen by covering his/her ears with an earphone playing non-stop music (see Figure 1). They had to finish a prototype in limited time through teamwork and test it in the end.

Figure 1. Students were Building an Egg Carrier

Another activity for team building was the “Rope Test”, where one student was blindfolded and the other was trying to help the partner reach the destination and cross the “rope gate” by merely giving oral instructions. After the tests, students were asked to share and discuss their feelings and experiences.

What students learnt in these activities was specifically valuable for the intended learning outcomes of collaborative learning and teamwork. In the egg case, students were excited at the beginning, depressed in the middle of the process due to communication obstacles and physical constraints, and accomplished happiness after successfully achieving the goal. They understood that each individual had his/her own strengths and weaknesses, but by working together they could accomplish the mission. They also realized that how difficult it was to communicate in a team, and acknowledged the power of prototyping as a tool of communication. The difficulty in communication was also encountered in the “Rope Test”, and trust between student individuals was seen as the base of successful teamwork. It was necessary for students to get aware of the importance of trust, as trust affects effective functioning of teams (Costa, 2003; Shagholi, et al., 2010).

In the group interview we did after the Capstone Bootcamp, Student2 in Group4 recalled: *“I realized that I was having self-protection behaviour subconsciously even I should have trusted that my partner would protect me safely. It is a little bit difficult for me to 100% trust someone. I think later on I will give more trust to others.”*

Meanwhile, open-ended, ambiguous project settings, and use of hands-on materials stimulated students’ creativity and ability to innovate. When compulsory one-solution success was no longer feasible as the final result, students became fearless to try new ideas.

2.4 Strategy Lecture - Doing Technical Projects from Business Perspective

The strategy lectures focused on transdisciplinary working life skills. Since students would conduct Capstone Projects in the coming semester with municipal or industrial partners, and work in an interdisciplinary and multicultural study environment, they were expected to realize that an excellent engineer should have cross-disciplinary knowledge in addition to subject knowledge. The cross-disciplinary knowledge is essential, for example, to understand the market and customers. In this context, technical skills are basic requirements, but non-technical skills are equally important.

The intended learning outcomes of a Capstone Project Course were derived from the attributes of top quality engineers that include: (1) motivation, (2) technical competence, (3) judgment and decision making, (4) innovation, (5) client/quality focus, (6) business orientation, (7) product development, (8) professional/ethical, (9) teamwork, (10) change management, and (11) communication (Davis, Beyerlein, Thompson, Gentili & McKenzie,, 2003). Business and product development theories were new notions to students who had many years of study under the traditional disciplinary lecture-based engineering education system. Therefore, the teaching team gave a “Strategy Safari” lecture on basic business-related terminology and theories. Students were required to employ the theories into their on-going technical projects from another course Embedded System and Application, and prepare a 10-minute presentation from product development and business strategic perspectives. The must-contained points in their presentation requirements are listed below:

- Factors creating operative effectiveness to your product/company
- Strategic competitiveness factors (position, trade-offs and fit) in your “startup”
- Analyzing where is the Product Frontier in your business

Good communication and presentation skills are particularly important in working life. Therefore, the teaching team assessed each group and individual by focusing on the business perspective content and presentation skills.

2.5 Designing Your Own Capstone Project Course!

Finally after all the above-mentioned activities, students were asked to conduct their final task – "Designing Your Own Capstone Project Course". In this task, students changed their role from a learner to a teacher and thus were able to think from teachers' perspective. The framework was based on the current setting of a Capstone Project Course at UTU (Taajamaa, Westerlund, Liljeberg & Salakoski, 2013; Taajamaa, et al., 2013).

Framework of the Design:

- Module size: 30 ECTS including a project and supportive courses
- Time Frame: From September 1st, 2014 to March 6th, 2015
- Stakeholders: Municipal and/or industrial partners

Requirements of the Design:

- Must contain intended learning outcomes.
- Must be a real-life learning situation—Design a real-life project
- Must include teaching methods, learning approaches and why
- Must contain preliminary timetable, project plan with budget and milestones, and project phases.
- Must include this "Capstone Bootcamp as an Introductory Course" as part of the module.

At the end of the Capstone Bootcamp, students' learning outcomes of the two weeks were practiced and examined. The goal was to integrate all the learnt knowledge and skills, and therefore students were asked to regroup and choose their theme of interest. All the themes were aligned into forcing the students to collaborate. First, each group was conducting independent work for their own part, whereas at the same time they had to remember that they were part of a 16-person big group for designing a 6-month Capstone Project Course. Students had 20 hours to prepare for the project and final presentation. The teaching team set several checkpoints and arranged a rehearsal 6 hours before the final presentation.

According to the observation of the teaching team, students encountered difficulties during the final task. We believe the reason for this is that they were used to following clear instructions from teachers. They felt unconfident and confused especially in the starting phase without teachers giving clear instructions indicating what was right and what was wrong. In the first checkpoint after 6 hours from the start, it was evident that the majority of the student teams were totally lost. Disordered presentations with lack of key points showed that they had no idea at all which direction to go; overlapping or conflicting contents between groups also showed that they did not have sufficient inner- or inter-group communications. After the teaching team's intervention, the students got to speed using design thinking methods such as need finding, background research, storytelling, and user studies.

Student3 in Group1's interview recalled, *"During the last assignment, even the teacher divided us into 4 groups, we were required to cooperate to finish one big task. I learnt how to communicate with others. For example, our group went to the wrong direction about our task and we corrected our work by communicating with other groups."*

It was also a reflective learning process for the students. As defined by Colomer, Pallisera, Fullana, Burriel and Fernández (2013), reflective learning is "a process that leads to reflection on all sources of knowledge that may contribute to understanding a situation, including personal sources and experience (p.365)". It has been proved to be a useful and appropriate approach for developing generic skills such as independent learning and adaptation to new professional situations (ibid.).

3 RESULTS – FEEDBACK AFTER THE CAPSTONE BOOTCAMP

3.1 Value of the Capstone Bootcamp

The reason for designing the Capstone Bootcamp was to prepare the students for the coming Capstone Project Course, which is part of their double degree study. It was planned to catalyze learning of transdisciplinary working life skills such as teamwork, open-ended problem solving, and communication skills. From the surveys and interview after the Capstone Bootcamp, we can see that students perceived a different experience. Teamwork (including communication, cooperation, and mutual trust) and presentation skills were mentioned with the highest frequency by students. These were perceived to be the most valuable things learnt during the Capstone Bootcamp and also the most helpful for their future (see Table 4). In addition, the Capstone Bootcamp also clarified the purpose of the Capstone Project, which was a new concept to the students. This was also the single biggest aim of the Capstone Bootcamp: to elaborate why Capstone Project Course is a necessary and important component in engineering studies.

Although all the students learnt valuable things in the Capstone Bootcamp, there were 3 out of 16 who did not see the value of learning from human sciences perspective. They did not understand the value of transferable working life skills for an engineer for whom technical skills have been the key factor for a successful career. This highlights the necessity of the Capstone Project Course in the engineering education.

Table 3. Interview regarding the Most Valuable/Important Things Learnt from the Capstone Bootcamp

Questions	Themes proposed by students	No. of Occurrences
What were the most valuable/important things you learnt from Capstone Bootcamp	Teamwork (communication, cooperation, mutual trust)	8
	Presentation skills	8
	Knowledge of Capstone Project	2
	Others (time management, self-knowledge, English skill)	3
How do you think the experiences and skills you learnt from Capstone Bootcamp will help your future in terms of studies, working life, or life in general	Teamwork (communication, cooperation, explore merits of team members, management skills, mutual trust)	8
	Presentation skills	5
	Others (Innovation capability, Tolerance to ambiguity, self-knowledge of own shortcomings and merits)	3
	Not sure yet	3

3.2 Learning Atmosphere, Teaching Methods, and Learning Environment

The initial idea of executing the teaching and learning in an intensive workshop format was to promote students' learning efficiency, create constructive pressure to the team setting, and introduce them to the goal-oriented way of doing projects. This was verified from the students' feedback. The majority, 11 out of 16, found the teaching methods to be good for their learning. However, 5 out 16 students gave opposite opinions. For example, the teaching team used encouragement instead of criticizing when giving comments on students' presentations, for which

Student2 in Group3 commented, *"I was confused whether what I did was right or not since the coach always gave positive feedback. I could not know which part I didn't do well."*

Student3 in Group3 commented, *"I prefer the coach to point out directly my problem. If always giving only positive feedback, I will be used to that and it cannot motivate me anymore."*

Student4 in Group4 commented, *"I am used to the Chinese traditional teaching methods and have not adapted to this kind of method yet."*

Some of the bias may be caused by the cultural difference and differences in traditional teacher-student relationship.

Selection of the learning environment followed general design thinking process guidelines: possibility to prototype, abundance of open space, scalability, and flexibility in changing the teaching and learning sites. In addition, the students were encouraged to seek new ideas from inside to outside the classrooms, which are usually regarded as formal learning sites. Based on the interviews, all these students gave positive feedbacks about the learning environment. It proved that the learning environment increased satisfaction and eased the tension caused by intensive schedule. Open teaching sites also made it easy to do group discussion and prototyping, and a relatively isolated environment could draw full concentration on learning and doing.

Student3 in Group1 commented, *"Our living environment was separated from the outside world, which somehow forced everyone to put his/her effort to the same direction… It was very good that our energy and attention were all focused on the work in the island".*

Student3 in Group4 commented, *"The natural environment in Seili Island was very beautiful and it gave me a relaxing learning environment..."*

Student2 in Group3 commented, *"The teacher created a relaxing and free learning environment which allowed us to exert our subjective initiative and creativity."*

Table 4. Interview regarding the Influence on Learning
by Learning Environment/Learning Atmosphere/Teaching Methods

Questions	Themes proposed by students	No. of Occurrences
How did the learning atmosphere/ teaching methods affect your learning	Encouragement and praise from teachers stimulated students' learning motivation and enhance their self-confidence	5
	Positive influence from a responsible and energetic teacher	4
	Relaxing and free learning atmosphere helped the learning and stimulate creativity	3
	The teaching method allowed full self-exploration and ensured timely guidance when needed	1
	Group work trained and intensified skills such as communication, cooperation	1
	Too many positive feedbacks hindered students to make further progress	3
	Being difficult to adapt to the teaching method	1
	Too much freedom and too relaxing learning atmosphere didn't help for learning	1
How did learning environment affect your learning	Learning space facilitated high efficiency of working	6
	Timetable helped to urge the work process	5
	Beautiful natural environment create a comfortable learning environment	5
	Separation from outside world allowed full concentration on the work	4
	Timetable was well planned that work and entertainment were both ensured	4
	Learning materials stimulate the learning interests	1

4 CONCLUSIONS – FUTURE DEVELOPMENT

Based on our Capstone Bootcamp pilot experience and observations, data from the student and teacher interviews, and their feedback, we summarized the following points as essential attributes for a Capstone introductory course, (1) ***short but intensive.*** The suitable length for a Bootcamp is two weeks. This requires that the content is designed carefully. For example, lectures, hands-on part such as prototyping, team-building activities, reading, and assessment with feedback should be arranged alternatively in order to maximize the learning effect, (2) ***teaching and learning.*** Teachers should lead and support the students' learning by other means than lecturing. In the Capstone Bootcamp, the teaching team was with the students all the time, sometimes as a listener, sometimes a co-player, and when needed, as an authority. Close relation can shorten distance and accelerate the formation of trust between teachers and students. This is important in dialogue based learning environment having a critical and interactive atmosphere. In one-way distribution of information, trust does not have such an intrinsic role in teaching (Curzon-Hobson, 2002), and (3) ***feedback and assessment.*** Assessment and feedback should be given constructively and right after the assignment. Using "I like, I wish" method (Leifer & Steinert, 2011) for feedback is recommended; (4) ***learning environment.*** Research shows that environmental factors have

impact on a learner's mood, satisfaction, motivation, and performance (Stone, 2001), and mood can affect people's comprehension experiences (Bohn-Gettler & Rapp, 2011). A good learning environment could make active learning happen, and hence catalyze students' deep understanding.

Students got strong motivation when changing a position from a learner to a teacher or a peer-to-peer coach. The change also clarified their own learning methods. By applying PBL, design thinking as well as prototyping methods and theories in the design of the whole Capstone Project Course, students were able to break the conventional vision of learning, and use independent thinking instead of passively following the given rules.

The Capstone Bootcamp course concept clearly needs further in-depth and action-based research on the design and implementation of the course. The research tracks could include cultural differences in learning outcomes, changes in the students' self-efficacy, impact on learning results in the actual Capstone Project Course, and the development of teaching methods suitable for a workshop environment.

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