CHALLENGE-BASED LEARNING CURRICULUM DEVELOPMENT: A SUITABLE FRAMEWORK FOR ENGINEERING EDUCATION (CONCEPT)

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ABSTRACT

Collaborative learning communities are becoming popular in engineering education. The department of Industrial Design at Eindhoven University of Technology (TU/e) has almost 20 years of experience in the organization of small-scale and challenge-based education (CBL). In Industrial Design, students work in 'collaborative communities' called *'squads'* that share an interest in specific application domains. Within the squads, vertical learning takes place and students from different bachelor

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and master years exchange experiences and learn together in a learning community while solving open-ended societal challenges. The purpose of the research was to map the characteristics of two ID *squads* (for the purpose of this study we will name the squads *Vitality and Crafting Everyday Soft Things (CEST)*, and study the educational elements influencing students' learning. In nature, the two squads share the same educational principles, however, the differ in the organization of education and the level guidance provided, decreasing, to some extent, the open-endedness characteristics of CBL. To conduct the study, we used the constructive alignment as a research framework to map the alignment between vision, teaching and learning activities and assessment of the *squads*. Results show alignment of the Intended Learning Outcomes (ILOs) with teaching and learning activities, and assessment in the two *squads*. The analysis draws attention to the similarities and differences between the two *squads,* specially in the manner of structuring learning. Finally, the suitability of the framework to analyse the CBL curriculum in engineering education contexts is demonstrated. This research opens up opportunities for future studies to investigate learning in small communities.

1 INTRODUCTION

Design is a discipline that fosters creative thinking to design products and systems and solve innovative real-life problems. Design is a complex, multifaceted problem-solving activity involving various cognitive abilities. Creativity and spatial ability are considered critical in design process. The work of a designer is perceived as 'making' the artifact or a description of what that artifact should be like and the communication around that specific design. Communication and socialization are essential elements of design education to prepare students for the workplace, therefore, replicating industry practices are important elements in the learning environment in which students learn and work collaboratively with other students [1]. Furthermore, communicating and socializing through participation in a community of practice [2] is a promising environment for learning representing authentic working places acquiring meaningful learning, developing competencies and skills, and shaping an identity as a designer.

From students' point of view learning communities are suitable environments that provide benefits for learning. According to Dodge & Kendall [3], students benefit from learning communities as they discover together *how concepts learned in one subject can be applied to projects assigned in another; can work together to solve class-related problems; reinforce students' own skills by teaching and mentoring fellow students in various subjects; learn how experts in each field coordinate classroom activities across disciplines; adapt to multiple faculty members' perspectives and classroom environments; make friends with students enrolled in the community; arrange a convenient class schedule of closely integrated courses; and increase their chances for success in personal, academic, and professional arenas'.* Furthermore, the goals and activities of the learning communities organized around workforce skills learning communities can stimulate students to practice skills, gain motivation and develop self-regulation [4]. Challenge-based learning

(CBL) is an educational concept and method by which students work together in open-ended, real- life and multidisciplinary wicked projects [5-6]. Within the context of ID, students work in *squads, i.e. learning communities,* to propose innovative solutions to global challenges.

In this study, we focus on investigating the characteristics of two *squads* as learning communities that foster students' learning. We apply a framework for this study to research two *squads* using the context of the constructive alignment [7]. The purpose of this study was to research the following questions:

1. What are the characteristics of the organization and structure of the *Vitality and CEST squads*?
2. How does the organization of the squads supports students' learning?

2 THEORETICAL CONSIDERATIONS

The notion of communities of practice has been related to the idea of having novice students to work collaboratively with experts in order to learn from each other and transfer knowledge and skills to less experienced students or staff [8]. Other researchers identify communities as 'discourse communities' or 'communities of practice' [2] as a means to socialize. Socialization in this regard is considered a powerful paradigm in which the scenarios to exchange experience from experts to novices provide useful opportunities for learning. Differences among these concepts lies in the formal or informal approach to learning. While Swales' idea of 'dicourse communities' focuses on academics interacting with different disciplines, Lave and Wenger's approach emphasises an informal way of learning where 'communities' and 'apprenticeship' are central to involving people based on common interests participating in a joint project or task.

Modelling expert practices has been characterized in the literature under the educational concept of 'cognitive apprenticeship [9] emphasizes processes employed by experts to handle complex tasks and teaching cognitive and metacognitive (as opposed to physical) skills and processes. Critical to the notion of learning communities and communities of practices is the theory of situated learning [2] in relation to CoP as a self-defined and self-developing approach. Researchers differ about the added value of external support such as facilitators or moderators. Other investigators of this concept [10], however, highlight the importance of the role of 'academic staff developers' who can be considered crucial in the 'harmonization' process when new academic staff join a CoP to streamline learning.

In the last decades, the concept of 'learning communities' and 'communities of practice' have become an instrument to materialize informal learning in organization, and, more specifically, for the purpose of this study, in learning organizations such as universities [6]. Collection of examples in this regard include 'models' for classroom organization of communities [11], or for the stimulate learning through a process of socialization [8] as a mean to promote practices that represent the workplace environments where informally learning occurs through the interaction with more experienced colleagues. The theoretical insight behind this rationale lies in

that learning takes place during the process of co-participating and co-creating by socializing with practitioners resembling authentic scenarios or withing the working places [12].

Grounded on these theoretical insights, we investigate the characteristics of the *squads* as learning communities, and more specifically, we pay attention to the impact of the educational organization of the *squads* on students' learning.

3 *SQUADS* AS LEARNING COMMUNITIES

Squads are the learning environments in which students learn and work together. Squads are thematic contact points for structural contacts between research and education as well as between academia and industrial/societal partners. Squads represent the expertise areas or disciplinary domains that give form to the content on the curriculum and cover all diversity in design elements and offer students a rich and diverse learning environment. Squads, as thematic learning communities, consists of academic staff, BSc and MSc students and external stakeholders, who collaborate on shared interests for the duration of a semester. The learning organization of the squads promotes selfdirectness and students can choose among a variety of projects. Furthermore, squads integrate the research interests of three to four academic staff members and PhD candidates, with the societal interest of clients, user groups and experts from practice, often represented by one or two Industry Liaisons, and the educational interest of 2nd and 3rd year Bachelor students and 1st year Master and 2nd year Master research students.

Cultivation and socialization processes allow students to become part of the previously described community. Teachers act as role models and model important values and implicit beliefs that students experience. The organization of learning fosters, therefore, feeling of community that stimulates the sense of belonging and inclusion amongst students, staff and partners. This allows the squad and the squad structure to become rich educational eco-systems that promote educational experimentation, innovation and differentiation.

The creation of smaller communities in a squad is an important mechanism to channel students' learning processes using horizontal peer learning (same year and same project) and vertical peer learning (different year, similar project and same squad). Peer learning is a valuable way for students to learn by receiving feedback from more senior students or equals and providing feedback to less senior students and equals.

4 METHODOLOGY

4.1 Context

Our study was conducted in the department of Industrial Design, in the context of two *squad* teams, which included several projects with a great variety in student characteristics (e.g., bachelor or master level) and project characteristics (team or individual projects, open-ended).

4.2 Data collection

Data were collected using a qualitative method approach to gain in-depth information about the structure of the squads, and the alignment between vision on education implemtation, Intended Learning Outcomes, Teaching and Learning activities, and Assessment. Observations of coaching situations were conducted for 1 semester. Interviews with students, coaches and experts from the industry were conducted at the end of the course. Interviews lasted approximately 45-60 minutes, and the participation was voluntary.

4.3 Participants

We conducted interviews and observations with coaches, industry experts and students from different levels (e.g. bachelor, pre-master, master, etc.). In total 31 interviews were conducted with students and 8 coaches were alongside with weekly observations of *squads* teaching and learning activities. An overview of participants can be found in Table 1.

Table1. Overview participants from Vitality and Crafting Everyday Soft Things (CEST) squads in this research

Participants	***Vitality Squad***	***CEST Squad***
Coaches	3 (1 internal 2 external industry coaches)	4 (2 internal coaches and 2 industry experts)
Teaching Assistant	1	
Bachelor students	3 (1 group)	4
Final Bachelor Project (FBP) students		1
Premaster	4	2
Master	9 (4 individual projects, 2 groups: 1 group with 3 and I group with 2)	2 master students.

4.4 Data analysis

Data were analyzed using thematic content analysis. An iterative process was followed where the two researchers read the transcripts of the interviews several times and followed an open coding approach. After several discussions, they developed a coding framework applied for all interviews**.** The Constructive Alignment model by Biggs and Trang (2011) [7] was used as a framework to map the characteristics *Squad* A and *Squad* B, in order to understand the differences and similarities of the organization of these two squads that may impact the learning of the students.

5. RESULTS

5.1 Mapping characteristics of the *Squads*

Despite the fact that *Squads* are different in expertise and thematic areas, they share similar educational principles and characteristics including the focus on the development of students' self-directed learning skills and the development of their professional vision and identity by working on projects where students can acquire and apply their design knowledge and skills. Another commonality among the squads is that they share the same way of assessing students learning with the use of a rubric that describes all competencies students are expected to develop (Table 2).

Table 2. Overview of general educational characteristics of the squads

Squads common educational chaterisctics	**Collaborative learning community**
Self-directed learning (SDL) is on of the pillars of the educational model.	**Coaching:** students are coached to make own choices on courses that best match their interest, at project level but also on career development. **Personal Development Plan (PDP**): students set learning goals and reflect on progress.
Professional Vision & Identity (PV&I)	Vision and identity as a designer are fully embedded in the reflections and designs students produce.
Application/acquisition knowledge	Knowledge is acquired and applied in design steps students go through in iterations. New knowledge is generated and used again by prototyping, etc. (Mid-term) Demo Day is a feedback and assessment moment to demonstrate designs, prototypes, etc. Students get feedback used to improve the product upo which they are assessed.
Assessment	**Rubrics** are used to provide feedback during the process, and finally, to assess students.

5.2 Linking vision with implementation: Constructive alignment from a curriculum perspective

The results suggest that squads provide an active learning environment of collaboration among students of different levels.

Regarding, constructive alignment both squads identified broad Intended Learning Objectives including knowledge acquisition, knowledge application, self-directed learning and professional development as designers. To achieve these objectives,

both squads have adopted a Challenge-based learning approach as means of their education.
This entails providing students with real-life, open-ended, and hands-on projects. The squads as learning communities provide to students a wide range of teaching and learning activities that aim to foster the ILOs.

The organizational set-up of the *squads* is similar (e.g. learning takes place in the form of a community where students from different bachelor and master levels provide peer feedback, learn from coaches and industry liaisons, and share themes' interests), promotes ***vertical learning*** as a structure.

Common activities targeting ***knowledge acquisition*** in both squads involved: weekly workshops on key topics that would assist students to get some baseline information for their project.

In terms of ***peer learning***, both squads provided an interactive open space for students to interact and learn from each other. ***Cross –coaching*** did take place in specific times of the semester before midterm and final demoday in *Squad Vitality* while in *Squad CEST* all coaches had a discussion with all groups on a weekly basis.

Regarding ***knowledge application***, in both squads students were encouraged to ***work on prototypes*** that were exhibited in the rooms so other students and coaches could provide feedback on their evolving efforts.

Self-directed learning was encouraged by giving to studnets autonomy to focus on interesting projects about them as well as coaching throught the semester to scaffold the process. In both squads, similar activities (e.g. individual feedback on PDP, coaching on self-directness and vision on professional identity, peer feedback, etc.) stimulate SDL.

Differences between the *Vitality and Crafting Everyday Soft Things (CEST) squads* are the structure provided to guide students learning. While in CEST s*quad* students get general information about organization of the activities and deadlines for delivery of products with no further indication of how deliverables must be submitted; Vitality s*quad* provides more strict guidelines on the form of the deliverables framing the students' expectations more closely. Finally, regarding ***final assessment*** as described above both squads employ the same rubric for assessing studnets'developmet of key competencies. For students assessment process was clear but still the criteria for assessment were considered quite subjective.

Table 3. Overview results mapping squads characteristics

Mapping characteristics squads	***Vitality Squad***	***CEST Squad***
CBL	General Intended Learning Outcomes (ILOs) for *Vitality squad* are provided. Open-ended: projects have no predefined end goal. Students need to define their own project objectives after consultation with external clients and their coaches Hands-on: designing interventions for behavioral change at an individual or systems level Real-life: projects focus on designing solutions for healthier lifestyles. Projects are often in collaboration with industry clients	General Intended Learning Outcomes (ILOs) for *CEST squad* are provided. Open-ended: Students formulate own project that meets own learning goals and fits within CEST s*quad* ILOs. No guidelines are given and therefore problem is ill-defined depending on students' own directions. Real-life: Projects framed in a design to contribute to societal and industrial interests. Students contact stakeholders (some time outside the university) to test or validate product. Multidisciplinary: challenges converge several disciplines, e.g. design, business, society, health components, etc., depending on the challenge goal.
T&L	Workshops are provided in the first half of the semester for students to acquire important baseline knowledge that could be useful for their project Weekly inspiration shot activities aim to foster students' creativity and develop skills (e.g., photography) that are useful for their project or deliverables Weekly coaching sessions Cross-coachings sessions in two predefined moments during the semester and ample opportunities for feedback on demand Workshops on PDP and individual coaching sessions on demand (Mid-term)Demo Day is meant to serve as milestones for students' project development and opportunities for practicing important professional skills	Workshops aimed at providing 'just-in-time' content and knowledge on a specific topic, i.e. are organized. Focus on provided knowledge needed to apply in solving the challenge. Friday morning feedback moment organized where coaches and industry experts provide feedback and advice. Peer feedback from students is organized and cross-coaching is from different experts to support students' learning. Individual feedback on PDP. (Mid-term) Demo Day is meant to encourage students to practice some professional skills

Assessment	Rubrics used to assess students' competencies development Assessment is based on various deliverables that assess not only students' final product but also highlight their progress and development throughout the semester (e.g., prototype, final report, final report on PDP, presentation etc)	Rubrics are used mainly for assessment. Rubrics are not fully always used for feedback.

5 CONCLUSIONS

In this study, the organizational structure of two *squads*, *Vitality squad* and *CEST squad* , as learning communities is investigated. Mapping the organization of learning following Biggs and Trangs' model (2011) [7] is applied and shows similar characteristics in the structure and alignment between the learning outcomes, teaching and learning activities and assessment. Among the most helpful teaching and learning activities include the provided workshops to support students' just-in-time knowledge acquisition, the feedback provided on progress as part of the weekly coaching, and cross-coaching sessions that supported students' learning in the design process. Students also appreciated the informal learning moments and collaboration between different groups and teams.

Likewise, vertical learning and self-directed learning are clearly identified in both squads. This shows that the ID educational model with its educational principles on learning is widely applied in the organization of the squads to promote learning. This has been confirmed in the students' interviews.

Interesting to see is that differences are mainly encountered in the level of structured guidance provided to the students when conducting project activities. Although guidances does not hinder learning, it highlights a difference in the application of the CBL educational form and SDL, in which students are expected to take the lead in the learning process.

Finally, this study shows the suitability of the famework [7] used to map and analyse the characteristics of the squads as a learning community, and more specifically, the alignment between the learning outcomes, the teaching and learning activities, and the assessment methods of the two squads researched.

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