COACHING PRACTICES IN CHALLENGE-BASED LEARNING: CHARACTERISTICS IN STUDENTS' PROJECTS

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ABSTRACT

Coaching students in CBL settings requires specific approaches. Although CBL has similar characteristics as Design-based learning (DBL), the educational concept and approach applied in the engineering programs at the Eindhoven University of Technology for over the past twenty years, CBL evolves from the DBL concept to emphasize the importance of addressing the sustainable development goals in education. Despite the fact that DBL coaching characteristics have been investigated, it becomes interesting to research these practices in CBL settings. The aim of this research study was to investigate coaching practices and explore differences among experienced coaches versus novice coaches, and the influence of the project set-up (e.g. group versus individual projects). The study was conducted in the department of Industrial Design, where students work on open- ended and hands-on challenges in groups or individually in the squad, an educational organizational form, where education and research come together. Project coaches and teacher coaches support the students to gain and apply knowledge and in the supervision of self-directed learning. The research method consisted of observations of coaching sessions (N=9), and semi-structured individual interviews with coaches (N=13 coaches) of various levels of experiences. Semi-structured interviews with individual (N=14) and groups of students (N=3) took place. Data were analyzed using thematic analysis and categories within the framework of coaching in Design-based Learning by Gómez Puente (2013) and the theoretical framework of Cognitive Apprenticeship by Collins (1991). Results indicate that the 3 most frequently used coaching practices are a) asking open-ended questions; b) providing feedback on progress in technical design and design process; c) encouraging students to explore alternatives for problem solving using different perspectives. The results are in line with teaching the discipline as design process are embedded in uncertain and creative undertakings in which students are motivated to think big in proposing solutions. Novice coaches focused more on technical design while more experienced coaches encouraged students to reflect on their learning process and to become more self-regulated learners.

KEYWORDS

Challenge-based learning, Design-based learning, Coaching, Integrated Learning Experiences, Standards: 1, 5, 8, 9

INTRODUCTION

Engineers in the industry and professional designers perform tasks with uncertainty and shape the process of developing a product by making relations between experiments, iterations in the design, making judgements to justify decisions, and communicating (Atman et al., 2007). Engineering problems in education are complex in nature and are designed based on challenging assignments. Students go through the process of solving problems by discovery and experimenting. They learn to analyze, synthesize, reflect and evaluate in loops while explaining the reasoning from findings in order to make decisions. In addition, practising the theory learned in courses or alike fosters cognitive retention (Karaman & Celik, 2008; Cavanaugh, 2004).

Coaching students to develop expertise as professional engineers and to gain an identity as designers require facilitating the process of learning to acquire and apply knowledge on the one hand. On the other hand, learning solving problems in complex and ambiguous settings ask for self-direction to address learning needs, identify objectives and search recourses (Findley, 2009; Lunyk-Child et al, 2003).

Design-based learning (DBL) and challenge-based learning (CBL) are suitable active learning methods that expose students to the nature of real life complex problems both in engineering and design-alike projects. DBL has been the educational concept and approach at the Eindhoven University of Technology (TU/e) for over the past 20 years (Wijnen, 1999; Gómez Puente, 2014). DBL has been applied in engineering study programs to teach students to look for answers to engineering problems while discussing and sharing knowledge in multidisciplinary teams that support learning in a meaningful manner. The characteristics of DBL and its effects on students' yields and projects' results have been investigated in the field of engineering education (Gomez Puente, 2014; Mehalik & Schunn, 2003; Apedoe et al., 2008). Following world-wide trends to incorporate the United Nations Sustainable Development Goals (SDG) in engineering programs, the concept of Challenge-based Learning (CBL) represents a suitable approach to educate engineers in developing technological solutions to current engineering and societal problems. Within the current developments and the emphasis of the United Nations SDG, Challenge-based learning is becoming a world-wide concept in engineering education. Within the context of the TU/e, CBL evolves from DBL and its characteristics and lies the emphasis in addressing the sustainable development goals in educating the new generations of engineers. Despite the fact that DBL coaching characteristics have been investigated, it becomes interesting to research these practices in CBL settings.

We conducted this study in the department of Industrial Design (ID) of Eindhoven University of Technology between February 2021 and June 2021. The ID department has almost 20 years of experience with organizing small-scale and design-based education. The organizational structure at the department of ID over 20 years has been the formation of educational communities, the so-called 'squads'. 'Squads' are defined as 'collaborative learning communities' that share an interest in a specific application domain. Within the squads, students work on open- ended and hands-on challenges in groups or individually. Vertical learning takes place in the squads where students from different bachelor and master years who work in projects and exchange experiences in a community of practices (Lave and Wenger, 1991). Students are guided by coaches, PhD staff and experts from the industry, the so-called, hybrid teachers.

Coaching is one of the pillars of the educational model of the department of ID. Students develop competencies, design own goals and drawn plans to achieve their identity and vision as designers. These core values of the ID educational model are essential to guide students in their growth as designers. The underlying principle is to support students to become self-directed learners and to reflect on competences development while designing and acquiring professional skills. In every project there is a project coach and a teacher coach supporting the students to gain and apply knowledge and in the supervision of self-directed learning. Students work for a semester and meet their coach weekly or bi-weekly.

Following the insights from the research literature on coaching of students' development, the focus of this investigation is to identify coaching practices in CBL and explore differences among experienced coaches versus novice coaches, and project set-up (e.g. group versus individual projects). We formulated, therefore, the following research questions for this study:
RQ (1) - What are the characteristics (indicators of behaviour) of coaches, when coaching students to support learning?
RQ (2) - What are the project characteristics that influence coaches' approach in coaching?
RQ (3) - What is the coaching style of experienced versus novice coaches to support learning?

THEORETICAL CONSIDERATIONS

There are numerous empirical studies associated with educational theories such as cognitive apprenticeship (Collins, Brown, & Newman, 1989; Collins, 2006) and situated cognition (Lave & Wenger, 1991) that highlight interesting results in students' performance. These theories are of interest in particular to create meaningful learning environments reproducing complex and real-life professional practice with authentic tasks. Specially, in the context of coaching, cognitive apprenticeship provides an excellent platform to supervise students' learning by *learning-through-guided-experience on cognitive and metacognitive skills by which students learn the problem-solving processes that experts use to handle complex tasks* (Gómez Puente, 2014, p. 186).

When embedding cognitive apprenticeship in educational settings, the role of the teacher is exemplified as a coach to facilitate the learning process of novices by experts. Examples from the literature illustrate the actions of the coach through modelling, coaching, scaffolding, stimulating reflection, articulation, and exploration (Collins, Brown, & Newman, 1989; Atman, Adams, Cardella, Turns, Mosborg, & Saleem, 2007). In scaffolding, we find instances of coaches in prompting open-ended questions to model and frame engineering thinking, facilitating the exploration of the design problem from different perspectives; stimulating critical reflection on the engineering and design process, promoting articulation on the design choices; and, providing feedback, pieces of information in a just-in-time form and tailor-made to the needs of students (Maase & High, 2008). Furthermore, the coach's role goes beyond supervising content-wise learning process as examples of guided instructional approaches focusing on meta-cognitive activities are also commonly employed (Massey, Ramesh, & Khatri, 2006). Likewise, when embedding situated learning scenarios the role of the coach is found as a customer, user, or expert in education (Martínez Monés, Gómez Sánchez, 2005).

Moreover, consulting the literature research within the context of (engineering) design we found characteristics of actions in coaching deeply related to the discipline of design. In these studies coaching actions are related to encouraging students to gain conceptual knowledge (design judgement, i.e. aesthetics coherence, feasibility, interactivity), design tasks (i.e. problem framing, balance trade-offs, valid experiments, focused diagnostics iterations and reflection), and strategies (procedural knowledge) as well as design process management strategies by using codes (i.e. complexity management, risk management, time management, etc.) (Ryan & Bernard, 2003).

For the purpose of this study we make use of a framework of coaching actions and behavior validated by the literature and empirical research within the context of DBL and alike in engineering education (Gomez Puente, 2012). This framework consists of an adaption of cognitive apprenticeship methods, situational learning strategies together with approaches to coaching students in design reviews (Adams, Forin & Joslyn, 2017).

METHODOLOGY

Research context and participants

The aim of this research study was to identify coaching practices in CBL and explore differences among coaches' experience (expert coaches vs novice coaches) and project set-up organization (e.g., group versus individual projects). Our study was conducted in the context of the squad, which included several projects with a great variety in terms of student's characteristics (e.g., students of bachelor or master level) and project organization (team or individual projects, open ended etc.).

The participants of this study were coaches of all squads of ID (See Table 1). All participants were informed via email about the purpose of the study and were invited to participate. In accordance with the Ethical Review regulations applied at the university, both coaches and students were asked to sign a consent form in case they agreed voluntary to participate in this research including participating in observations and interviews.

Table 1. Overview of research method, research instrument and participants

Qualitative	Instrument	Total N	Descriptive characteristics
	Observations of coaching sessions	9	Individual projects:5 Group projects: 3
	Interviews with coaches	13	Male: 9 Female:4 Expert:11 Novice: 2

Research methods

We collected data on coaching interactions using the following methods:

Observations of coaching sessions aimed at attaining an overall understanding of the coaches' behaviours during those interactions. Due to COVID-19 all activities (e.g. coaching sessions, students' group work, workshops and presentations, etc.), took place online. Thus we asked coaches and students to record their coaching sessions and shared the video with the researchers. Participation was voluntary and we asked participants to share examples of their coaching sessions during the project process, i.e. initial phase, project implementation, and final phase of the project. Observations were facilitated by recording the coaching sessions using the program Microsoft TEAMS after students and coaches provided their consent for recording.

Interviews with coaches were conducted at the end of the semester to gain in depth understanding of their own behaviour with coaching in CBL. We conducted interviews with coaches who had extensive experience (> 7 years) in coaching (expert coaches) and less experienced (<5 years) (novice coaches). Interviews with coaches were guided by the framework of Adams (2016). Coaches were asked for concrete examples of how they coach students across different design tasks and processes and asked to indicate differences in their coaching style depending on students' level of education and project characteristics. Likewise, coaching approaches on identity and vision were also collected. These interviews lasted approximately 60-90 minutes.

Data analysis

Data collected via video-recorded observations were analyzed using the framework of coaching in Design-based Learning (Gomez Puente, 2013) as guide to identify coaching behaviors. Table 2 provides an overview of the coaching behaviors coded during observations. Two independent researchers at the beginning of the data analysis phase coded independently using the same 1 video framework. Then they discussed and compared their coding approach and agreed to a common strategy. After both researchers coded their videos, they both cross-coded each other's 1 video for validation purposes.

Table 2. Overview of framework used for the analysis of coaching sessions and interviews

1. The coach formulates open questions to -FOQ
2. The coach acts as an expert, customer; gives information on specifications – AEF;
3. The coach provides feedback on progress on presentation skills, team work – FPS;
4. The coach reviews progress on plans, proposal, etc., RPP;
5. The coach provides feedback on evolving efforts (e.g. coaching on progress in technical design, design process, data collection, testing methods) PTD;
6. The coach supports students in reflecting on and explicating rationales for technical design, argument formulation, and decision making, RER;
7. The coach supports students in case of difficulties (just-in-time teaching) JIT;
8. The coach uses methods/tools (worksheets, drawings, examples, etc.) to guide the team, UMT;
9. The coach encourages students to articulate engineering terminology during regular meetings and presentations, AET;
10. The coach encourages students to look back on previous actions/tasks and reflect what they learned from them; EAP
11. The coach encourages students to learn from other students' plans, learn from experts knowledge application in problem solving experiments, LEE;
12. The coach observes students during implementation of activities, OIA;

Data collected via interviews were analyzed using thematic analysis, which consisted of the following steps: familiarization with data, coding, generating themes, reviewing and defining themes (Clarke and Braun 2013). In our analysis, we followed a deductive, theory-driven approach and the theoretical framework of Cognitive Apprenticeship by Collins (1991) and the framework of Adam (2016) in coaching processes were used as guides to formulate our themes.

RESULTS

Analysis of video- recorded observations

Results indicate that the 3 most frequently used coaching practices included: a) asking open-ended questions, b) providing feedback on progress in technical design and design process and c) encouraging students to explore alternatives for problem solving using different perspectives. In Figure 1, an overview of the coachers' behaviors, the frequencies in terms of the number of times coaching behavior actions were performed are included.

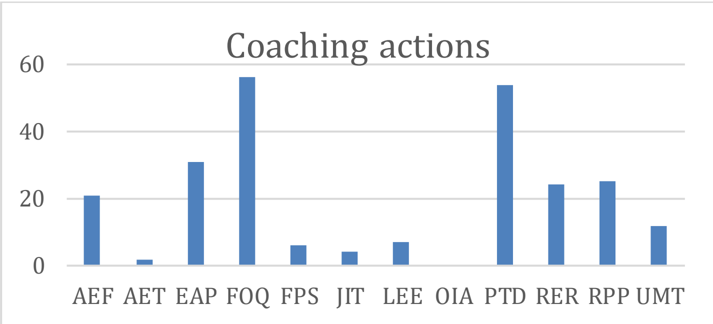

Figure 1. Overview of coaching actions performed during coaching sessions

Coaching actions during design process: the influence of project and student characteristics: Coaches reflected on the different aspects that can influence their coaching. Three aspects seems to play an important role namely: a) the level of education of students b) whether the project is a group project or individual and c) whether the project is open-ended or it is an existing project with some predefined constraints. Table 3 provides some details and quotes.

Level of education: According to coaches, students at the beginning of their bachelor, pre-master and master students who have done their bachelor studies in other faculties, they need more guidance and support in the design tasks and process as they are used in ID. On the other hand, final bachelor students and master students, who have also conducted their bachelor studies in ID, are considered more independent due to the fact they have conducted multiple design projects and they are more familiar with ID processes. In addition, depending on their level of education, students find different aspects of the design process more difficult. For example, students in earlier years of bachelor might need much more guidance at the beginning of the project to develop ideas, while more experienced students need more coaching to balance their focus on a specific idea, while keeping the bigger picture of their project in mind.

Group versus individual projects: Whether students work as a group or individually also plays a role to coaching. In groups, coaches prefer not to interfere with group dynamics and let the group choose what direction they want to follow in their project. In individual project students do not have other peers to brainstorm their ideas or feel insecure about making final decisions so coaches choose to support students in this direction by thinking along with them and encouraging them in decision making by linking it to their overall vision and professional identity.

Open ended versus defined project: The type of project also plays a role in coaching. When students start with a very open-ended project they need more coaching at the beginning to narrow down their focus and objectives. This is especially true for Final Bachelor Projects, which are individual projects. When the project is very detailed and concrete, the challenge for coaches is to help students to be creative and learn things within the constraints of their project.

Table 3. Overview of project and student characteristics influencing coaching actions

Students' level of experience	*In the lower year, during idea generation, coaching is very much needed. In the last part, where they're they' re building prototypes and stuff, there is less coaching needed, because it's mainly it's clearer what needs to be done. And in the higher year projects, it's mainly seeing the bigger picture and making them see the bigger picture and have them not drown in details, elements of the process or in detailed expertise areas (expert coach).*
Group versus individual projects	*So I think with group projects, it's just easier, like students have more experience doing group projects. And if it's individual projects, you really have to think along with them. Right, like, so what did you do before on your prior projects? What are your interests? What did you like about them? (novice coach).*
Open ended versus defined project	*So they get a specific brief on what they have to design. And very easy when it's very detailed. But it depends on the level of students, right? bachelor, they need more guidance masters a bit less, If it's really broad, you need to definitely guide them a bit. Give them at least two three different options on what they could do (novice coach).*

Analysis of interviews

Coaching actions during design process: *coaches' views based on their coaching experience:* Interviews with coaches showed that apart from student characteristics and project characteristics, coaches' own experience can also influence their approach. Table 4 gives some examples of the themes identified.

Using open-ended questions throughout design process: Despite years of experiences, all coaches in this study reported that asking open and critical questions to students was their main coaching approach to encourage students to elaborate and explain their thoughts, justify their design decisions and monitor and evaluate their design tasks and actions. This result is not surprising as the design process relies on uncertainty and ambiguity in which creative thinking plays a major role.

Coaching on time planning and time management: One common characteristics among all coaches was the emphasis on time management. They suggested the importance of supporting students to make a good plan at the beginning of the project but set frequent checkpoint to revise this plan during the project. In this aspect novice coaches reported to be more active in supervising students planning more actively, warning them for possible setbacks to ensure that students can finish their project within time.

Coaching students on decision making: One of the most difficult aspects during coaching according to novice coaches is helping students to become more autonomous and empower them to make decisions. Experienced coaches actively abstained from deciding on behalf of the students and usually the most commonly reported coaching approach was to provide them with some options. Encouraging students to detail the pros and cons of different options and discuss them with their coach, was a commonly mentioned approach by both experienced and novice coaches.

Encouraging student to reflect on their design process
Crucial to the process of design is to help students reflect and learn from that experience. Especially expert coaches emphasized the importance of frequently taking a step back and evaluating their progress and reflect on it.

Coaching students to perspective from doing to learning
Expert coaches during their interviews put a much larger emphasis on helping students through the project to develop their professional identity and shift their focus from doing a project into learning compared to novice coaches.

Coaching students to balancing big picture with details
Expert coaches reported more interventions where they actively zoomed out to help students have the bigger picture of their project in mind. The importance of keeping in mind the big picture is relevant in all stages of the project according to expert coaches. Novice coaches tend to help students to start from more concrete projects and guide them on a technical level more closely without making explicit references in their interviews about reflection during the project on the bigger picture.

Coaching students to different perspectives
Novice coaches reported the importance of exposing students to a diversity of ideas early in their project as a way to avoid guiding to students in only one direction. Expert coaches also encouraged students to contact other experts but at a later stage when students need more technical support on a specific area.

Table 4. Overview of coaches' actions

Using open-ended questions throughout design process	***Open question to justify decisions*** *"If you press the push notification locker opens? Is that the flow you're envisioning?"(expert coach)* ***Open question to articulate reasoning*** *So some of the students will stick on a very specific idea, usually the first idea they had. So that means they didn't the dig much survey on this domain. So that's why as a coach, I will ask a lot of critical questions for the student to explain, "why you want to do this?" and maybe suggest he can go some different directions (novice coach)*
Focused on students' professional vision	***Start from students' motivation*** *"I start from students motivation because this is what matters after all" (expert coach)* ***Try to understand who the student are*** *"what did you do before on your prior projects? What are your interests? What did you like about them?(novice coach)*
Coaching on time planning and time management	***Set expectations from the start*** *"There are multiple iterations. Plan them out. You have to sit down and unpack with each other. Think of the methodology, the other job is to develop a mechanism of what you have done and what you're going to do…"* (expert coach) ***Constant revising of plan***

	“I know that at the beginning time planning is perfect but delays and other things happen during the process so we set checkpoints and we ask students to reflect on their plan and revise it if needed” (novice coach)
Coaching students on decision making	***Think along with student*** *“You come into an ethical ‘split‘ if you speak on behalf of a child. A child is has autonomy and is wise, and you can’t have a device who thinks for the child, and you can’t forget the parents. The opinion and feelings of the child needs to be taken into consideration.”(expert coach)* ***Suggest many different options*** *But I also always try to then come up with a richness of possible ideas. Because if I come up with one suggestion, you know that next week, they have adopted that idea and come up with should take over your idea and continue with that. Whereas it's not meant to say this is what you should do (expert coach)*
Encouraging reflection on process-how you learn	*“How do you probe you’re the locker?...You said QR code but I want to use remote unlocking through Bluetooth. This has consequences for interaction and that’s missing from your argument…” (expert coach)*
Coaching students to perspective from doing to learning	*“So I think that's, that's one of the first things to changing that perspective, that you're not doing it to pass to pass courses, but to develop your to develop yourself and to see, what you want to what you want to learn from it, and how its contributes to your, to your development” (expert coach)*
Coaching students to balancing big picture with details	*“It’s mainly firstly challenging them to see the bigger perspective or provide them with a bigger perspective and have them reflect on okay, how important is that thing that I'm working on? In the larger in the larger part?” (expert coach)*
Coaching students to different perspectives	*“We have the cross coaching so I really like that because that means the student can get the different perspectives from different coaches is not like the only gather the people from my side because of the usually the mono feedbacks really kind of, well, we'll only direct them to the one specific direction but I think it's important at an early stage to explore the diversity of the idea”. (novice coach)*

CONCLUSION

Results indicate that the DBL coaching framework used is a suitable instrument to analyze coaching situations in DBL/CBL contexts. The comprehensive framework facilitates the visualization of coaching practices and contributes to shed light on experience coaches’ behavior. For educational practitioners and more specifically for organizations to set-up training programs for novice coaches, the framework acts as a guideline for the professionalization of teachers (e.g. A buddy system so that the novice coaches can learn on-the-job and observe many different coaches; to make implicit ID experience more explicit; to encourage peer reflection; to adjust coaching to students’ level; to develop own coaching identity; and, to understand that if students fail that is not due to personal failure).

Finally, this study has opened up new opportunities for further research. Next steps include exploring longitudinally the effect of coaching practice on students' knowledge acquisition, application and overall professional development in the context of the squads.

Limitations of this research study

Despite the sound research approach planned for this study, the research encountered some limitations. First of all, this study has been conducted during the COVID-19 pandemic period. This has had serious consequences for the implementation of the study as coaching sessions between students and coaches were conducted online and no face-to-face meetings took place. Although online meetings were recorded and the researchers had access to the information, observations of coaching sessions alive count with more value to perceive optimally, for instance, how feedback is processed by the students and the effect on their work. Secondly, despite the fact that the coaching sessions were recorded with the consent of students and coaches, not all coaching sessions were recorded throughout the implementation of the semester projects. This impeded to follow the coaches and the students' group in all phases of the design process. Only some recordings of coaches were made available, and in some cases only one recording was delivered. Therefore, we are careful to make strong conclusive judgments of the findings of this research study.

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