Tools to empower learners in Challenge-Based and Design-Based Learning projects

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ABSTRACT

The paper investigates how tangible tools can empower learners to become self-directed in Design-Based Learning (DBL) and Challenge-based Learning (CBL) activities. DBL and CBL encourage collaborative learning and students' autonomy by offering project openness and enabling the development of self-directed learning skills. However, this autonomy introduces challenges related to managing uncertainty and maintaining control. Key components in handling these challenges involve goal setting, planning, and reflection. Based on literature research a set of qualities of CBL and DBL, important for developing self-directed learning, are presented. The paper examines how tools can support process monitoring, and cultivation of reflective learning practices. Three design cases are presented, each offering unique strategies to support self-directedness. Having been developed by design students, the designs incorporate input from interviews, co-creation sessions, user observations, and expert validation. Key takeaways include the role of tangibility in realizing sharing, openness, and guidance, in making explicit communication of implicit concepts.

CCS CONCEPTS

• Human-centered computing; **• Human-computer interaction (HCI)**;; **• Applied computing**; **• Education**; **• Interactive learning environments**;; **• Interaction design**; **• Interaction design theory, concepts and paradigms.**;

KEYWORDS

Challenge-Based learning, Design-Based learning, Tools for learners, Tangible tools

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1 INTRODUCTION

1.1 On DBL & CBL

Design-Based Learning (DBL) and Challenge-based Learning (CBL) are examples of modern STEM education in which students learn by working in a team on open and realistic (design) challenges that are engaging and meaningful to the students [30]. While CBL emphasizes the element of providing a challenge and centers on engaging students realistically in an endeavor mimicking some professional practice, DBL is centered around an iterative design process involving testing, collecting feedback, evaluating, and revising a concept or prototype [37].

Theoretically, both these can be recognized as examples of 'socio-constructivist learning environments', in which learning emerges within the process of sharing, planning, and doing together. Their learning objectives are not limited to learning concepts or theory alone. CBL and similar approaches were found to be particularly good at teaching how to apply knowledge and turn declarative knowledge into functioning knowledge [3, 32]. Moreover, learning goals also critically include various domain-related and general competencies such as collaboration skills, presentation skills, learning skills, and self-regulation skills. This set of skills shows some overlap with the so-called '21st-century skills' as well as developing 'soft' skills that are important for engineers in 'professional life' and/or the 'business world' after finishing studying [20].

Of these, self-direction skills are crucial, as they play a role in CBL and similar learning environments, both as a prerequisite for learning, and a learning outcome. Self-directed learning refers to a learner's autonomous ability to manage his or her own work and learning process, by perceiving oneself as the source of one's own initiatives, actions, and decisions responsible for work and learning [29]. It is a highly autonomous process of recognizing needs, setting goals, integrating resources, taking proper study strategies, and reviewing [24]. This reflective nature is widely accepted as relevant in engineering and engineering education. But it doesn't necessarily need to be an individual process [4]. In CBL/DBL students are encouraged to work in self-directed ways while engaged in group-learning settings, involving tutors in the learning activities to improve efficiency.

1.2 The problem

Clearly, DBL and CBL are approaches that provide learners with the opportunity to steer their learning process. In particular, as a result of their open nature, but also as a result of a multitude of their other characteristics, such as the (design) challenges being realistic and engaging, the element of sharing and collaborating, the alignment of assessment with the broad spectrum of learning goals, the emphasis on formative assessment on both the learning outcomes and the process (rather than a summative assessment of cognitive outcomes alone), and the minimization of 'direct instruction' [29]. Hence, these socio-constructivist learning environments are generally supportive of the development of self-directed working and learning [17, 29].

However, how CBL and similar educational models exactly work in this way is not yet fully known. Much is still unclear about how/when self-directed learning emerges in CBL, and how self-directed learning is fostered in CBL. In particular, we do not exactly know which elements are critical for optimizing the development of reflective self-directed working and learning in CBL-like learning environments.

1.3 Situational and contextual interactions

Collaborative learning such as in DBL or CBL, entails the interplay of cognitive, social, and organizational factors [13]. There is a complex interplay between learning contexts, learner characteristics, and learning activities. For example, showing that different combinations of scaffolding and guiding elements are used with learners at different ages and with different learning goals [15]. Leary et al. state that '*self-directed learning is mediated heavily by student and teacher perceptions, by environmental factors, and by underlying models that are used (or not) as part of a larger intervention'* [17:193]. We only partly know what student characteristics are critical and how these interact with aspects of the CBL-type environment, the learning goals, and the environment the CBL takes place in, to produce CBL-like education that effectively promotes reflective self-directed working and learning. These various aspects need to be interwoven in the design, implementation, and assessment, and we need to develop design rules or principles to apply, and what qualities of CBL are crucial in promoting reflective self-directed working and learning [13].

In this paper, we describe exploratory research to develop design knowledge about how tools can be used to support these complex processes that support self-directed learning in CBL and DBL.

1.4 Research questions

To contribute to the understanding of how to design tools to support self-directed learning in a CBL and DBL context the research questions addressed in this paper are:

- What qualities of CBL/DBL are relevant for supporting and empowering learners in self-direction in DBL/CBL?
- What are the key characteristics of tools for supporting and empowering learners in self-direction in DBL/CBL?

The first question is addressed in the related work section, specifically in section 2.3. This section gives an overview of CBL/DBL qualities. The second question will be addressed using a 'research through design approach' [38]. We will describe 3 design cases in which (teams of) industrial design students have interactively designed solutions for empowering learners in a self-direction in DBL/CBL. From their theory-informed comparative description of these design processes and outcomes, their commonalities and differences, some highlights and insights emerge that could help guide future comparable design projects.

In preparation for the design analysis, we have conducted literature research to collect qualities of CBL that should be taken into account when designing tools to support learners.

2 RELATED WORK: QUALITIES OF CBL/DBL RELATED TO SELF-DIRECTION OF STUDENTS

In this paper, we highlight two sub-processes in self-direction in CBL: 'goal setting' (particularly taking place at the start of the project) and 'reflective self-direction' (mainly acting as a mechanism to keep on track of the project and/or individual learning).

2.1 Goal setting

Goal setting is a process in which an individual or team works towards a clear and shared view of the desired outcomes (goals), which then serves to guide and regulate activities. Clear goals provide a clear direction for working and learning and were found beneficial for students' motivation and achievement levels, in particular when specific and requiring a moderate amount of challenge [19]. Hence, the setting of clear goals is a prerequisite to self-steering during the run of the project.

In CBL/DBL, goal setting should comprise both individual learning and developmental goals, as well as team-level project goals. Goals may compete with each other for priority and effort. In particular, team goals related to project outcomes or products in CBL can suppress the setting or realization of individual learning and development goals [22, 35].

Setting team goals requires a shared view of the task, situation, envisioned outcomes, possible solution(paths), and envisioned outcomes [18, 28]. Setting individual goals requires an overview of one's strengths and weaknesses, as well as possible ways to work on learning points and how this could take place within the project. The latter also requires adequate negotiations resulting in a favourable division of labour and prioritisation of project activities. Apart from skills, this requires a high degree of mutual trust in the team and the expectation that teachers will only address such 'areas for improvement' formatively (and not factor them into summative assessment).

2.2 Reflective self-steering

Reflection is a metacognitive process based on prior knowledge and experience that individuals actively and deliberately analyze their actions, and their outcomes to create learning [8]. Reflection can increase the depth of knowledge and learning and may help identify areas that are missing or processes that can be improved [5].

Here we focus on reflection that supports learning and working and its direction in CBL. Such reflection is fundamental to self-direction and a common element within CBL/DBL. Schön [27] distinguishes reflection-in-action and reflection-on-action. Reflection-in-action takes place during teamwork and learning with the perspective of facilitating the process and progress. Although reflection is inherent in CBL/DBL, it is not always easily recognized as critically relevant within engineering and engineering education in general [e.g. 6]. It seems less prominent in science-oriented engineering disciplines but is crucial in design and design education [14].

Reflection-on-action is taking a broader perspective and can view learning and working as an object within in wider (e.g. societal) and/or personal (developmental) perspective and can include reflection on the developing 'professional self' as an emerging professional engineer [30].

2.3 (Developing) self-direction in CBL

Literature research points to several characteristics of CBL/DBL settings that are likely to influence self-direction, which can potentially be supported by tools and can provide a basis for the analysis of the design cases.

2.3.1 Openness. There is no simple direct relation between the openness of CBL/DBL and developing self-direction [17]. It seems more plausible to assume that openness of CBL tasks works more or less like a 'necessary condition' than a factor impacting self-directedness. Openness may create the space necessary for students the develop self-direction, but still, students can choose (not) to take 'ownership' and engage in self-direction [12].

2.3.2 Teamwork Sharing and Collaboration. CBL involves the interplay of social and organizational factors, as well as cognitive factors [13].

Students must define and organise work as a team, define and assign subtasks and team roles, and create an appropriate division of labour. For individual participants, this means (learning) skills to contribute constructively to these processes, and in particular to learn to take responsibility for their part of the work and develop skills in playing the different team roles. This includes different aspects, such as dealing with uncertainty and aspects related to self-perception, self-confidence, and identity [12].

Team learning also includes a number of identifiable cognitive and metacognitive steps such as sharing, discussing, negotiating, and making decisions. Particularly relevant is building a shared understanding of the task, situation, expected outcomes, possible solution(s), and expected outcomes [18, 28]. In particular, the depth of discussion was found to be crucial for learning [36]. For example, negotiation is crucial for balancing the focus on individual learning and team goals. Decision-making is necessary to resolve conflicts and as such encourages in-depth discussion. Without it, group progress is hampered.

2.3.3 Scaffolding. While openness is an opportunity, reducing openness, providing scaffolds, or even compelling assignments could increase the chance students actually choose to engage in self-directed working and learning. Here we define scaffolding as *a pre-designed structure of teaching materials, arrangement, and teacher interventions (including guidance) that support the students with respect to adequately running the process of doing CBL in an increasingly self-steering manner.* Scaffolds (and/or supplementary guiding) are needed to develop self-direction [23] and can contribute to improving peer questioning and co-regulation [15]. Scaffolding is meant as temporary support for learning and should gradually decrease as students become more advanced, e.g. by using a 'see-model-observe-fade' strategy [32].

Scaffolds can take various forms, such as scripting where the material/teacher provides structure to the project in terms of a set/sequence of sub-tasks) [21], providing questions where the material/teacher indicates that the particular activity will be needed at a certain point, or asking questions – reflective questions in particular [31]. To support self-direction in CBL/DBL, particularly invitations or cues for providing each other with feedback and moments of reflection can be part of the scaffolds.

2.3.4 Preventing Cognitive Overload. Adequate scaffolding (and guidance) are critical to prevent students from being overwhelmed by the openness, complexity, and content demands of CBL [16]. Kirschner et al. [16] stress that the total of all cognitive load put upon the students should be limited to prevent 'cognitive overload'. Cognitive overload has a destructive impact on learning, especially on higher cognitive activities such as self-direction. Complex subject matter, (design) projects with a multitude of (conflicting) stakeholder interests, and large or highly heterogeneous teams, increase the cognitive load - possibly at the expense of the cognitive capacity available for reflective self-direction. Such situations call for more extensive scaffolding.

2.3.5 Constructive Alignment. Several authors highlight the importance of aligning assessment procedures with CBL/DBL goals and activities [32]. In particular, 'classical summative and/or knowledge-based tests' are assumed to be destructive with regard to the type of reflective self-directed learning that CBL/DBL stands for. There are concerns that such assessments would deter students from self-directed learning and would encourage 'studying for the test'. According to Sze-yeng and Hussain [29], good alignment [3] of assessment in particular with learning objectives and activities will help students engage in self-direction.

2.3.6 Adequate Feedback and Formative Assessment. Feedback is key to all learning [11] and contributes to promoting reflection when accompanied by explanations in particular [15]. Feedback can be given by the teacher or by peers. Programming moments for asking and giving feedback and guidelines for giving productive feedback can be useful. Formative assessment also provides feedback, but has a 'formal' nature, is deliberately focused on specific learning and/or team goals, and is often done by the teacher. Therefore, it forms a dynamic framework that structures and shapes self-directed work and learning skills [29].

2.3.7 Motivation, Encouragement, and Fostering Confidence. As such, CBL defines an intrinsically 'empowering' learning environment, which promotes students' motivation, engagement, and self-confidence [30]. Taconis and Bekker [30] explain this commonly found result by showing how the design of CBL ensures good performance on all three factors that are crucial for intrinsic motivation according to self-determination theory [7, 33]. Including playful qualities in interaction design can contribute to students' motivation.

2.3.8 Support for Goal Setting - Navigating 'Uncharted Waters'. To demonstrate successful and increasingly powerful self-direction, the self-direction level of the student and/or team must meet the requirement of self-direction needed in the project. By definition, CBL/DBL requires students to enter 'uncharted waters', which is demanding and can easily cause uncertainty or anxiety.

This holds especially true for less experienced and weaker students. They may lack knowledge of the domain and an overview of the discipline, which may hinder them in content-dependent decision-making and planning. Novice students may also lack the skills to design their own learning objectives and self-directed learning [23].

To make goal setting manageable and effective, specifically tailored scaffolding is needed. Goal setting should be a structured process and/or made independent of content knowledge and skills [23]. Scaffolding that provides structure and indicates the steps to be taken can be more effective in goal setting than reflection-type scaffolding. Reflection-type scaffolds clearly have a place in online self-direction.

2.3.9 Visualization. In goal setting and reflection, a large part of the process can remain hidden. In particular goal setting involves concretizing abstract elements such as values, certain points of view, and exploratory ideas. Yet, these need to be shared and jointly worked on in CBL/DBL. Visualization could help the team to create a shared mental model of the task, possible solutions, and the aspired outcomes [34]. It helps to concretize, share, and form a solid basis for discussion and decision-making. A visualization tool can also help structure the process, e.g. by symbolizing abstract project management concepts as concrete tokens, which can be jointly substantiated, ordered, or otherwise manipulated. Adding concrete visibility would also create a platform for aligning goals and reflection at the individual and project level, and make these processes more visible and coachable for their teachers.

2.3.10 Tangible tools. Tools to support self-directed learning can be digital or tangible. The use of digital tools can have benefits such as data storage, personalization, and insight into the work of other students, but can also cause students to experience problems with power/powerlessness, lack of agency, and privacy [26]. Tangibility (and playfulness) can help lower barriers to sharing, feedback, and reflection, encouraging everyone to play an active role. Tangibility has been reported to improve group learning and performance [25]. On the other hand, there may be a danger that physical materials can limit reflection and abstract thinking by locking the learner into an 'action mode' [25]. To counter this, it seems important that a facilitator actively promotes that the material is primarily used as a basis for deliberate reflection.

3 METHODS

3.1 Research-through-design method

The overall approach is a research-through-design (RtD) approach that employs the act of designing as a means of generating knowledge and understanding [38]. This research includes three design cases in which designs of learning environments are created using an iterative design process, following the Stanford Design Thinking Process [1], together creating a basis for conducting RtD analyses of the design qualities of the designs.

The projects were created by two final bachelor students, each working on their own project, and by a first-year master team of the Industrial Design (ID) Department at the Eindhoven University of Technology (TU/e) (The Netherlands). The students worked on the design projects for a period of 16 weeks. They involved various stakeholders in their projects including, prospective users (learners (first-person perspective) and teachers), educational experts, and experts from a company in educational products.

The prototypes developed in the design cases can be seen as 'hypotheses' for how the research question can be addressed. Knowledge from the design cases is distilled by drawing insights from the evaluations within the design cases and design analysis conducted examining the design qualities (linked to the CBL/DBL characteristics mentioned in section 2.3) of the developed prototypes.

4 DESIGN CASE ANALYSIS

A design analysis was conducted by describing what processes were supported by the prototypes and examining how certain functionalities and experiences are expected to support the empowerment of the learners in a self-directed learning environment. The design analysis is described in the design qualities sections by mentioning how the designs addressed the CBL/DBL characteristics (highlighted in bold) mentioned in section 2.3. These sections focus on the CBL/DBL characteristics that were most salient and distinctive for the specific design case, the overall insights per CBL/DBL characteristics are provided in the discussion section.

4.1 Design Case 1: Peakquest

4.1.1 Design Context. The project aimed at conceptualizing a tool tailored for bachelor students within an ID curriculum to support and enhance their capabilities in self-directed learning and goal-setting in an interactive way. The final design consists of a physical toolkit with a connected digital app that facilitates the quick application of self-directed learning methods for new bachelor ID students by letting them set out their own learning paths when working on a group design project.

4.1.2 Design Qualities Linked to CBL/DBL Characteristics. The design of this tool is characterized by its **playful and engaging approach**, drawing inspiration from the metaphor of a 'treasure map' to provide users with a relatable and familiar framework (see Figure 1). It aims to enhance engagement and contextualization by guiding users through a structured process towards well-defined **goal setting**. Based on the five layers of the Solo Taxonomy [2, 3] and the SMART goal [10], the **tangible toolkit** offers guided templates for physically laying out and filling in steps, facilitating students in **visualizing connections** and achieving completeness. By breaking down goals into manageable 'bite-sized' tasks, the design **reduces cognitive load** and promotes ownership and self-directedness in goal-setting. The toolkit provides some form of **scaffold** by providing templates, e.g., for coming up with goals.

Additionally, the inclusion of gamified elements and self-competition features fosters motivation and personal growth within

Figure 1: Screenshot of the digital app of the Peakquest prototype that provides an overview of the steps to reach the selected goals (left) and the physical toolbox that supports students in laying out a path of learning goals and process activities on tiles (right).

a team context. The design further incorporates digital support by providing users with **a visual overview** of all planned goals and progress via an accompanying app. Playful reminders and checkpoints within the app serve to maintain motivation and keep users on track, while a chatbot feature offers suggestions for reflection and further development, enhancing the overall user experience and supporting continuous improvement.

4.2 Design Case 2: MirrorMirror

4.2.1 Design Context. The primary aim of this design was to support the process of reflection for ID students engaged in DBL or CBL projects. It focused less on supporting goal setting. The physical game helps ID students to hold up a metaphorical mirror, to check if they are following their passions, staying true to their goals, and how much they are aware of their vision.

4.2.2 Design Qualities Linked to CBL/DBL Characteristics. The second design, a physical board game, serves as a **visual representation** of the project path, offering a metaphorical approach to engagement rather than a formal one (see Figure 2). Through varied shapes, colors, and patterns of the tiles, the game provides metaphorical inspiration, encouraging players to think creatively about their process. Its use is divided into two rounds. First, the game focuses on intuitively laying out the project process. Secondly, the game supports and **scaffolds** the team to go through a semi-structured reflection on various elements through reflection cards, ensuring the exploration of key topics. The **openness** in using the board game provides freedom and control over the game, where players intuitively arrange puzzle-like pieces, enhancing intrinsic motivation to structure reflection and fostering a sense of self-efficacy. The **team activity** fosters discussion and shared experiences among players.

Some interesting insights from the user testing included: that students prefer to do the reflecting without the coach/ teacher, because they feel safer expressing their mind, that they tend to frameless challenging goals so that they are confident that they will make them, and that they appreciated they were motivated to not only reflect through text, but also through drawing. Finally, although the reflection process intends to drive the student's learning process, they seem to feel it is mostly used for being assessed. It is important to create a better balance between a positive connotation of increasing their intrinsic motivation and possibly pride when following a reflection process and the more negative connotation of it is 'only' being used for assessment.

4.3 Design case 3: Aimion

4.3.1 Design Context. The goal of this project was to make an interactive & dialog-based tool for students, teaching assistants, and teachers at the TU/e to reflect on and monitor their CBL activities. This led to the creation of a workshop based on physical and digital tools shaped in a modular circle of tasks working towards a self-defined challenge and process.

4.3.2 Design Qualities Linked to CBL/DBL Characteristics. The third design builds the puzzle of handling an open-ended challenge by starting from the inside and moving outward. Step-by-step students decide on their **learning goals** and create a physical **visual overview**, allowing for direct changes and **visualization of connections** (see Figure 3).

Teamwork and characteristics, including discussions on strengths and weaknesses, are integrated, along with alignment on the challenge and goals. Planning is emphasized to provide a comprehensive project overview and intrinsically set deadlines.

Figure 2: Usage of the MirrorMirrir prototype, where a group of students builds their project path and then uses reflection cards to support their learning process.

Figure 3: The use of the AIMION tool in a workshop, where students consider the challenge (inner ring), their learning goals, the values embedded in the project (middle ring), and project activities and deliverables (on the outer ring).

The dialogue-based nature of the process encourages team discussion and decision-making. This overall cooperative process fosters team alignment and mutual understanding among members, providing a **tangible, step-by-step guide** to goal-setting and planning. Teacher or tutor guidance provides scaffolding throughout the process, while separate follow-up sessions enable ongoing reflection and adjustment based on literal and figurative layers over time, promoting continued engagement and self-steering toward progress.

5 DISCUSSION

The design cases explored how to support self-directed learning in a CBL and DBL context. By looking at the commonalities and differences of the design decisions made in the three cases, as described in the Design Qualities sections, we can provide insights and design knowledge about how to design for some of the key characteristics (as mentioned in section 2.3) of self-directed learning in a CBL and DBL context.

The design projects discussed above share a set of design decisions that collectively contribute to how the designs aim to support students engaged in self-directed work. The main design implications include: embedding **teamwork and social interaction** to support the overall learning process, sharing goals, making implicit concepts explicit through communication and visual sensemaking, and including playful and tangible design elements to support the engagement and motivation of learners.

Firstly, the designs emphasize the **role of teamwork and social interaction** to support social and collaborative learning. Discussing plans and insights, both personal as well as project-related, with peers is assumed to contribute to the students' learning process and motivation [15]. Furthermore, the projects all focus on providing **support for goal setting**, with the teams discussing and as such getting and giving feedback, on both individual and collective team goals, fostering a balance between personal growth and collaborative achievement. While setting personal goals helps the learners in developing intrinsic motivation, the shared goals support creating an alignment of intentions and a mutual understanding between team members [18, 28]. Supporting social interaction is embedded in the 'interaction rules' of the games and tools that have been created.

Another commonality of the tools is that they provide support to handle **the openness of interpreting the challenge or design brief**, by supporting students by framing learning goals and related activities and reflecting on the decisions made. This helps the students in taking control of some of the freedom in the learning context.

An important aspect of these designs is the commitment to **making implicit thinking explicit**. This transparency in thought processes aligns with the more holistic challenges centered on **decreasing cognitive overload** and supporting negotiation [16]. The transparency is supported by the **physical and tangible nature of the tools**, supporting teams to develop a shared mental model [34]. It informs the learners in their understanding of the challenge and the importance of setting goals and reflecting on them. This process is supported by the emphasis on critical reflection, and inspiring discussion, as well as an intentional effort to lower barriers to participation and communication.

The tools are designed to be flexible and intuitive offering users a simple interaction with the tools itself and with other team members, tutors, or learners. The dialogue-based nature of the tools, structured by guiding questions and prompts, which function as a **scaffolding structure**, often asks learners to write down or lay out their thoughts. This in turn further reinforces a collaborative and reflective approach. Furthermore, different strategies were used to provide some **scaffolding** for setting goals, such as including the verbs from the SOLO Taxonomy [2] as semi-structured prompts.

All designs consisted of **a tangible element or physical tool** supporting the **visualization** of the various processes. The tools enable individuals to see changes being made directly, be able to influence them immediately, and understand how different elements connect to form a cohesive whole. This incorporation of tangible tools with game-like qualities serves as a unifying feature to provide a dynamic and interactive dimension to project planning and monitoring. Various **playful properties** have been used to create a more **motivational environment**, such as choosing a game board to visualize the project (MirrorMirror) and visualizing the learning path as a path in a virtual world (PeakQuest). It allows the learners to get "out of their head" and out of the often text- and computer-based settings. The use of modular shapes, creating a metaphorical map, facilitates step-by-step, structured visual overviews. This visual sensemaking approach ensures clarity, ease of comprehension, and decision-making by focusing on organizing or writing out one's thoughts. At the same time, the use of a metaphor or narrative, such as a 'treasure map' engages its users.

The digital potential of tools was only examined to a limited extent. The PeakQuest tool examined the benefit of digitalizing data to create a scalable and interactive overview able to track the progress of multiple goals at the same time. The AIMION tool has been translated to the online MIRO environment to explore the flexibility of its form and use, making it more accessible in online contexts or for larger groups of participants.

5.1 Future Work

The tools presented in the paper have been made by students, with input from diverse stakeholders. The case studies were design explorations to develop an understanding of how to support self-directed learning in a CBL and DBL context. While the outcome of the various evaluations provided positive feedback, no formal effect measurements were conducted to determine whether students improved their knowledge and skills, e.g. in terms of their confidence in following a self-directed learning path. Nor has the effectiveness or experience of the tools been tested outside of the context of the students' university, or often outside of the context of ID students.

While the design cases so far have made only limited use of digital technologies, it is interesting to examine further what role technologies can play in the context that has been examined in this paper. The field of Computer Supported Collaborative Learning (CSCL) aims to leverage technology to overcome the challenges associated with distributed collaboration and enhance productivity, effectiveness, and creativity by focusing on shared meaning-making [15]. For example, technology can play a role in helping students to work in settings that are more authentic and have opportunities to directly test their ideas and solutions, with the tools providing more dynamic feedback or scaffolding [15]. Furthermore, because of the possibilities of data storage technology can, for example, play a role in tailoring and personalizing designs or tools to make them more fitting, engaging, or motivating to students.

While technology and tools can support students' learning processes, it is also important to examine further how this process can best be facilitated, or 'orchestrated' by the teachers. As Dillenbourg [9] discusses in detail, a successful application of tools to support learning can only be realized by looking at how the use of the tools is orchestrated by the teacher. Further research is also needed to develop an improved understanding of how the design qualities explored in these design cases can be embedded in a self-directed learning environment and influence various aspects of the learning context. Furthermore, the insights from the design cases have shown that many factors in the ecosystem of the learning environment influence how such tools will be used. For example, the amount of trust that students have in the team and with the teacher, but also how such a tool is embedded in the wider curriculum.

6 CONCLUSION

The work presented in the paper aimed to provide information about what knowledge from theory can inform design decisions in designing tools for self-directed learning in a CBL and DBL context. To that end the paper first provided an overview of what qualities of self-directed learning and of CBL and DBL can be considered when supporting learners. Furthermore, the paper presented initial insights about design knowledge that can inform the design of tools intending to support students in self-directed learning environments. Key takeaways include the role of tangibility in realizing sharing, openness, scaffolds/structure, and guidance, to boost motivation and confidence as well as making explicit communication of implicit concepts through discussions and visual sensemaking.

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