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A Thematic Analysis of Engineering Students' Experiences of Teamwork in Problem-Based Learning*

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Changing modes of production and emerging technologies and economies require capable employees equipped with a set of diverse competences. These competences are no longer limited to specific disciplines but include broader emphasis on generic competences applicable across various contexts involving a variety of professions. Consequently, collaboration and teamwork are also two central generic competences in engineering practice and pivotal elements in engineering education. However, collaboration and teamwork competences are often only superficially addressed and moreover, not based on students' experience. This study address engineering students' experience of the constituent parts of teamwork competences in a systematic integrated problem-based learning (PBL) environment and how these can contribute to curriculum development. Conducting a thematic analysis of students' written competence profiles (n = 130) results in the construction of five themes concerning students' teamwork competences: finding complementary competences, establishing teamwork culture, preventing and managing conflicts, awareness of self and others and shared situational awareness. Each theme is illustrated by several components emphasised by students and exemplified by excerpts useful for curriculum development or learning activities supporting development of specific competences. The thematic analysis furthermore exemplifies how generic competences are perceived as enablers of disciplinary problem-solving in teams, and how systematically integrated PBL supports the development of a wide variety of teamwork competences. The article concludes that students are acutely aware of team members and their position in a team while maintaining flexibility enabling potential responses to anticipated or unknown challenges found in the internal or external environment of the team.

Keywords: engineering education; PBL; PjBL; generic competences; students' experience of teamwork; competence development

1. Introduction

New modes of knowledge production and globalisation have resulted in increased demands for competent and capable employees to keep pace with emerging changes brought by economic and technological innovations. To meet the requirement, generic competences are often emphasised as remedies for both employers and employees as epitomised in various frameworks promoting conceptions of lifelong learning, professional skills, 21st-century skills or key competences [1–3]. Generally, generic competences are characterised as the competences needed to succeed across a variety of workplaces [1] and as competitive advantages not only for companies and nations but also for the individual employee positioned in a labour market undergoing a transition from lifelong employment to lifelong employability [4–6]. Generic competences can furthermore be delimited to a given professional practice, where boundary-crossing competences are viewed from a specific professional practice, such as the engineering practice [7].

For engineers, the emphasis on generic competences entails an increased attentiveness to not only technical competences but also competences to work in teams for collaborative problem-solving, deal with ambiguity, consider the social aspects of the profession and assess the social consequences of the proposed solutions, to name a few [4, 8]. The perception of engineers as solitary problem-solvers needs to be jettisoned to leave room for a different conception of engineering as a human performance involving distributed expertise, multiple aspects of practice, and a 'tacit ingenuity', which is challenging to transfer to an educational realm [9–11]. Often spheres of professional expertise overlap and require translation between participants engaged in practice, implicitly highlighting that learning indeed is a core concept embedded in practice [10].

Studies have aimed to identify the most important generic engineering competences by use of meta-analysis of practitioners' perceptions of important competences for practices [12] or synthesis of frameworks concerning both disciplinary and generic competences [4, 13]. Consensus of important competences appears across studies, albeit with different emphases dependent on the professional subgroup [4]. In their review, Passow and Passow [11] found distinct clusters of competences identified by practising engineers, graduates and teaching staff. In all subgroups, competences in planning and time management, problem-solving,

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communication, and teamwork had top ratings. Other important competences also include decision-making, creative thinking and dispositions to learn, lead and to have an interdisciplinary approach [2, 12]. Generally, for engineering education to support students' development of generic engineering competences, connections to complex and contextually grounded practices are emphasised [14], in which technical and social competences are entangled in a professional practice [8, 10]. The intricacy of professional practice is not easily captured [9, 15] but can be approximated by applying paedagogical approaches, such as conceive-design-implement-operate (CDIO) or problem- and project-based learning (PBL), in which an explicit focus on both generic and disciplinary competences can be found [7, 16, 17]. Moreover, educational approaches promoting student-centred and active learning, such as PBL are often considered viable options for supporting generic competences development for students [3, 4, 17].

Whereas most studies relating to generic engineering competence take their point of departure in practitioners, competence models, and reviews and theoretical conceptualisation [11, 13], only a few studies address how students perceive the development of generic competences during education. In one of these studies of engineering students' perceptions of generic competences development in PBL, it is concluded that even though most studies concerning generic competences development have an emphasis on teamwork, the constituting parts of teamwork are mostly implicitly addressed, typically combined with other types of generic competences [18]. Few studies present theoretical constructs of teamwork as a foundation for planned activities set in a PBL environment. These constructs contain various aspects, such as defining a shared purpose and goal, psychological safety and interpersonal trust, role clarity, mature communication, productive conflict resolution and accountable interdependence between team members. Knowledge of the construct's multidimensionality is necessary for students to identify and reflect on teamwork competences in situ [19]. In their review of teamwork competences aimed at HR personnel and researchers, Cannon-Bowers et al. [20] nonetheless 'imposed' some order on a field often riddled with inconsistencies and confusion and found several overarching dimensions describing teamwork skills, including more detailed definitions, subskills and alternative declarations in the reviewed literature [20, p. 344–346]:

- Adaptability: a process in which a team adjusts strategies according to gathered information.
- Shared situational awareness: a process in which team members develop compatible models of the internal and external environment and include skills in reaching a shared understanding.
- Performance monitoring and feedback: abilities of team members to provide and receive task-clarifying constructive feedback and includes the ability to monitor the performance of team members.
- Leadership/team management: an ability to direct and coordinate activities, assess performance, assign tasks, motivate team members, planning and organising, and establish a positive atmosphere.
- Interpersonal relations: an ability to optimise the quality of team members' interaction by resolving conflicts, reinforcing motivation, and utilising behaviour fostering cooperation.
- Coordination: a process of organising team resources and activities to ensure tasks are completed within temporal constraints.
- Communication: a process of clear and accurate exchange of information in a team using proper nomenclature and includes the ability to clarify or acknowledge the received information.
- Decision making: an ability to gather and use information, use sound judgment, identify alternatives to select the best solution, and evaluated the consequences.

The definitions of each dimension in [20] are described as abilities and processes and are not confined only to the development of individual skills, but also to maintaining collective processes that transcend individual abilities. Pivotal to accomplishing the diverse skills, teams must develop shared mental models concerning the interaction of roles and relations. Theories of team performance are based on very different conditions and professions, thus making generalisations difficult. Competences and the performance of teams must be then understood in relation to a specific context as well as the characteristics of tasks, work, and the competences of the individual members and the team. Individual attitudes and orientations towards teamwork have a significant impact on team performance [21]. This has been noted previously by Sandberg [22], who in a phenomenographic study found conceptions of work to precede what competences the worker developed and used in performing said work. According to Raven [23], competence is what appears in relation to role requirements and personal abilities set in specific situations. Further, the author problematises the hitherto 'pervasive' problem in the competence movement, mainly the accepted notion that people of the same profession or job title by default perform the same. Instead, the focus ought to be on

what people are doing. Following this train of thought, promoting generic teamwork competences then requires not only a rationalistic conception based on external aspirations but also students' experience of teamwork activities. Hence, using a general framework to guide our research and analysis is limited insofar as students do not necessarily share the same mental models as those outlined in the skills dimensions provided by Cannon-Bowers et al. [20]. Still, in this article, we adopt an understanding of competence aligning with Raven [23] as *something* that appears as a result of the role requirements and personal abilities. In an educational context, we believe such an open-ended definition provides ample opportunities to capture students' competences as something in flux throughout their educational trajectory.

1.1 Research Question

Teamwork is a key competence in engineering education as well as in engineering practices, and we argue that graduates should be able to reflect on and articulate experiences of teamwork to develop a reflective practice to identify and develop attitudes and competences in a team. The aim of this study is therefore to analyse teamwork competences from a student perspective. The research question is as follows:

> *How can engineering students' conceptualisations of teamwork competences enrich the understanding of teamwork as an asset in curricula development?*

To answer the research question, we analyse students' reflective writings (n = 130) on their competence development. Using Aalborg University (AAU) as an extreme case of systemic integrated PBL, we shall conduct a thematic analysis of engineering master's students' conceptualisations of teamwork competences in written PBL competence profiles. The aim is to outline a specified framework of competences to inspire intended learning outcomes for teamwork in the curriculum. In the following, we shall elaborate on the context of the study and the methodological considerations regarding the collected data.

1.2 Framing of Research Context and PBL Competences

All students at AAU are situated in a systematic integrated PBL where projects often last the full duration of the semester and encompass a workload of 15 ECTS. The remaining 15 ECTS points are often divided among subject courses with content intended to be used as part of the project. The AAU model is then based on both canonical subject matter and student-initiated and participant-directed problem-based and project-organised learning, where students are responsible for most elements included in the specific project. This provides students with opportunities to experience several aspects of working in teams and to develop enabling competences to this end. Further, students across all educational programmes are introduced to PBL, albeit with a local interpretation.

Although PBL is among the student-centred approaches at the forefront of potential learning approaches to support generic competences development, students at AAU still face problems when asked to identify and conceptualise generic competences as practice over time that becomes habitual and ritualised [14, 17]. According to Kolmos et al. [24], generic competences has previously been an explicit part of the PBL curricula practised at AAU, but the explicitness has diminished during the last decade. Hence, a new institutional strategy aimed at identifying and including generic competences progressively in formal curricula has been implemented [25].

As noted earlier, competences do not exist in a vacuum devoid of context, and at AAU generic competences are directly related to PBL and are thus institutionally dubbed PBL competences and qualified as non-disciplinary and transferable across contexts. The PBL framework at AAU follows the overall principles elaborated by Kolmos and De Graaff, who emphasise that every student project takes its point of departure in a problem normally defined by the students themselves. The authentic and exemplary problem serves as a start for a social learning process organized in teams of five to eight students. In the context of participant-directed work, the pedagogical concept of exemplarity becomes an important aspect in qualifying the selection of subject matter and content in the respective projects to adhere to overarching learning outcomes [26].

Further, the aspect of experiential learning described by Dewey [27] and since Kolb [28] emphasized in PBL promotes activation of prior knowledge through reflecting on a selected problem. The activation of prior knowledge has previously been acknowledged as a vital component in PBL in general [29]. However, even though experiential learning is highlighted in much of the background literature of PBL, students' teamwork practices at AAU become increasingly tacit during education [24]. After the first and second semester, few outcomes specifically address PBL in the formal curricula, suggesting that the theoretical aspects of PBL are either facilitated by supervisors, students, or not at all [25]. Making students reflect fruitfully on experiences on their own has previously proven difficult [30]; however, when aided encouraged to

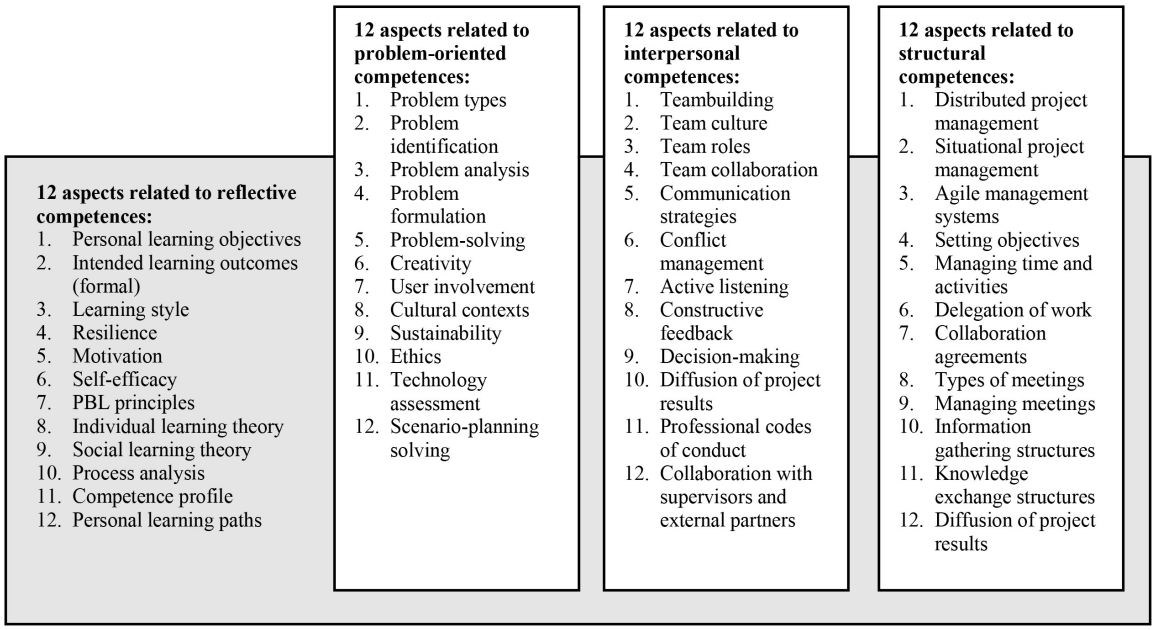

Fig. 1. PBL competences [14].

do so, most students are capable of reflecting on their practice [31].

To facilitate a reflective process, PBL researchers from AAU held three-hour PBL competences workshops for master's students in the Faculty of Engineering and Science (ENG) and the Technical Faculty of IT and Design (TECH) during the spring of 2021. In the AAU strategy of 2016–2021, one of the aims was to integrate intended learning outcomes (ILO) specifically related to PBL, and the formulation of ILOs was facilitated in alignment with four overall areas of PBL competences: problem-oriented, interpersonal, structural and cross-cutting reflective PBL competences [14]. In Fig.1, the four overarching categories deduced from the existing learning principles at AAU were further aggregated in a framework of aspects, which was used as an inspiration to initiate dialogue in the development of ILOs at the programmatic level rather than an exhaustive list [14]. The very same framework was used to initiate students' reflection on PBL competences.

The learning activities related to students' articulation of PBL competences were divided in four parts: (1) self-study by reading the developed guide for PBL competence profiling [32], (2) attending a workshop for students to learn how to move from PBL experiences to PBL competences, (3) articulating their PBL competence profile and (4) reflecting on the feedback from facilitators for potential profile revision. The aim was to increase students' awareness of often tacit PBL competence development in each of the four competency domains. At the workshop, students were asked to reflect on their existing PBL practice to identify competences and then select and exemplify competences based on experiences from practice to describe competence development in situ. The expected outcome of the workshop was a one-page competence profile highlighting individual strengths framed in a vocational perspective. To support the workshop, various forms of content were supplied to students. Among the content were short videos concerning theoretical aspects of PBL covering each of the four competency domains, and the written guide provided additional questions and examples to aid students with identifying, clarifying and describing their developed competences. Rather than suggesting one preferred way of identifying competences, different perspectives were presented, allowing students to take different routes when profiling their competences, such as a practical view of what they had been doing so far, a performance view of what they had been doing well or a developmental view relating to perceived potential for improvement. Lastly, each profile was evaluated and approved by workshop facilitators, and an approved competence profile was a precondition for participation in the concurrent project examination.

Each of the authors of the article has been involved in the development or facilitation of PBL competence workshops. The first author has facilitated and co-facilitated workshops on educational programs not included in this article. The second and third authors have been central figures in the development of the overall PBL competence framework used in aiding students in the reflection of PBL competences.

2. Data Collection and Methodology

The data were collected as a part of the assessment process of PBL competence profiles. The selection of competence profiles was discussed among teaching staff involved in the workshop to find educational programmes in which students' profiles were most varied to ensure the breadth of students' experiences, see Table 1.

The competence profiles were on average one page of students' descriptions of generic competences in the four competency domains using experiences from their PBL practices. Since students select and frame specific competences, there is a chance of social desirability and potential bias in the profiles. This cannot be omitted but is a caveat to be considered in this type of data. Overall, the individual profiling thus entails differences in emphasis in each of the four competency domains. The profiles can be characterised as elicited texts where participants are involved in the creation of data, and guidelines for elicited texts range from detailed instruction to minimal suggestions and share methodological implications typically found in conventional questionnaires and interviews [33, 34]. In this case, the application of a predefined framework with distinct clusters and related examples may influence students' descriptions in various ways. However, we believe this influence to be ambivalent, and, as previous research has shown, unaided reflection is a difficult task for students [30, 31]. To this end, rather than looking at selected competences and predefined concepts used by students, we chose to focus on the emphasised experiences of practice.

2.1 Analytical Framework

Thematic analysis is a method for identifying, analysing and reporting patterns and themes across qualitative data, which is applied to categorise and organise experiences emphasised by students. A theme is not determined by quantity but how it captures important aspects relating to the research question [35, 36]. The thematic analysis conducted is constructivist in its approach, meaning that experiences are considered as socially produced in specific contexts and structural conditions, and the researcher is an active participant in the construction of themes. Practically, this means that themes constructed and analysed in the following were informed by theories and experiences from a PBL environment, and researchers applying the same constructive approach to our empirical corpus may reach different results [37]. The deductive and informed approach to coding also means the perception of themes emerging as hitherto hidden gems did not apply to this case. To develop a systemic and transparent approach, all profiles were imported into Atlas TI for thematic coding and aggregation. The analytical process is iterative and reflexive and requires attentiveness to how codes are aggregated into themes during the process [36]. Braun and Clarke [35] outline six phases in a thematic analysis:

1. Familiarisation with the data. In this stage, documents were reviewed and coded by reading and rereading the data, searching for meaning and patterns. Here, subthemes were based closely on students' phrasing, i.e., some students noted that PBL afforded opportunities to 'find their own way' when dealing with an open-ended problem.
2. Construction of subthemes. In the process, several subthemes were constructed in an iterative process through which initial codes of interest to the researcher were generated and constructed based on the research question.
3. Searching for themes by aggregating initial codes. Here, potential tools such as mind maps or thematic maps can be used to visually organise themes and relationships between codes, themes and levels of themes. Previously, we noted that some students emphasised the opportunity to find their own way, which we aggregated in a theme called self-directed learning. Fig. 2 displays our first iteration of constructing themes at different levels: the oval figures are placed at the top level and named according to overarching competences found in research literature; grey squares with dotted lines are the second level; and white squares are the third level. 'Project management,' 'Communication' and 'Reflection' are included in the figure as they are connected to central elements of teamwork but are not a central focus of this research.
4. Reviewing and refining themes on two levels.

Table 1. Department and educational programmes represented in the collected data

Department	Educational Programme	Participants
Materials and Production	Operations and Supply Chain Management	43
Electronic Systems	Control and Automation. Communication Technology Signal Processing and Acoustics Product and Design Psychology	50
Built Environment	Geography Water and Environmental Engineering Transport Engineering	37

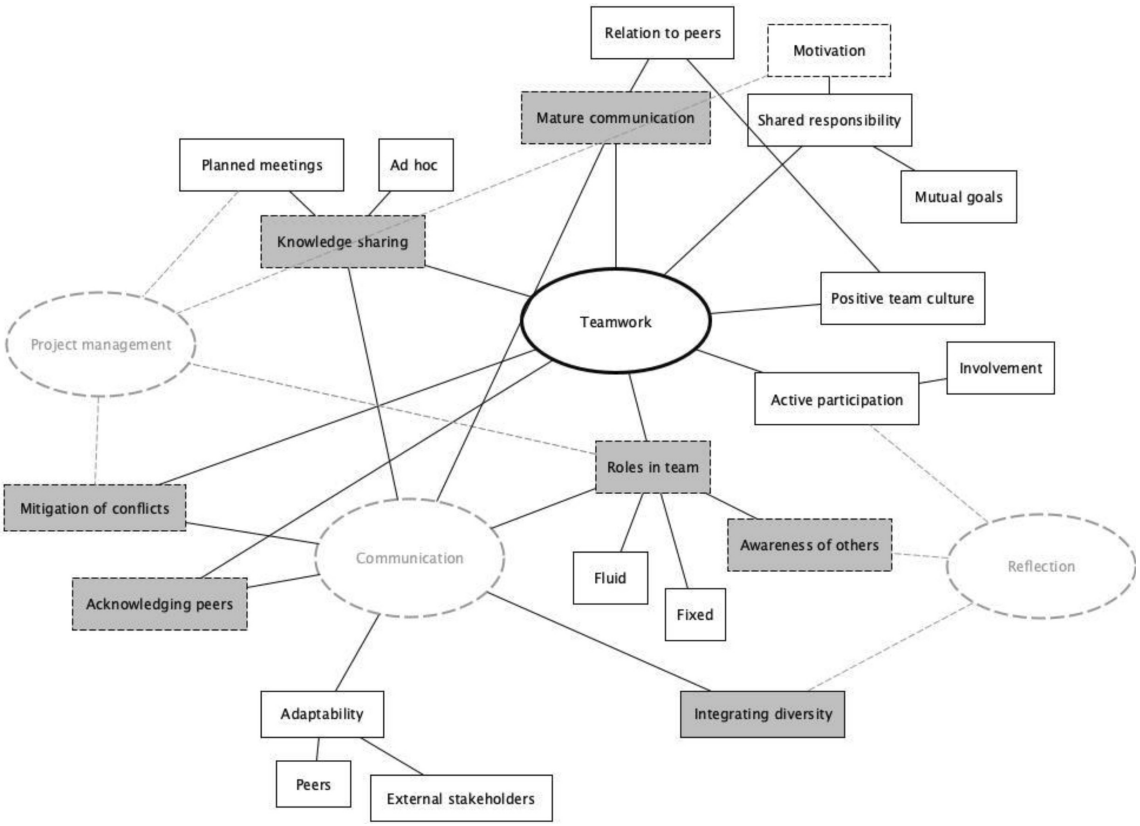

Fig. 2. First iteration of construction themes and connections.

First, a review of coded data was extracted to assess the coherence of patterns. Secondly, the validity of individual themes in relation to the story of the dataset was considered to ensure consistency and coherence in the included excerpts extracted from the competence profiles. Two iterations of reviewing and refining were performed to assess students' individual descriptions of teamwork in relation to the overall corpus of competences profiles. In the first iteration presented in Table 2, we created three general themes aggregating various codes and subcodes into fitting categories based on a simplified scheme of a linear process of teamwork inspired by Tuckman [38], i.e. the creation and formation of teams, supporting culture and actual performance. The bold text in "*Codes and subcodes*" were themes previously placed on the same level as the general themes seen in Table 2, but in the attempted aggregation these were included in other general themes. However, the linear conception of teamwork did not fully capture the fluidity described by students, and in our view, a temporal depiction of students' teamwork would neglect the contextual changes affecting what competences come to work. Our second iteration are presented in section 3.

5. Defining and naming themes to identify the essence of a theme and clear definitions of themes. Reviewing our constructed themes and codes for further refinement and clearer definition resulted in five overarching themes with corresponding experiences found across the empirical corpus.
6. Producing the report.

Table 2. First iteration of reviewing and refining themes and codes. Codes and subcodes are based on students' excerpts, i.e., students who describe of initiating teamwork by finding students with complementary competences [finding complementary competences] or descriptions of an increased awareness of team members work and dispositions in relation to changes in role requirement [situational awareness: knowledge sharing, shared responsibility.]

General Themes	Codes and Subcodes
Establishing teamwork	[*Finding complementary competences*: Roles in team, awareness of others, integrating diversity]
Creating team culture supporting efficient teamwork	Team culture, conflict management; [*increased reflexivity*: active participation, acknowledge peers and listening, relation to peers]
Performing teamwork	[*Situational awareness*: knowledge sharing, shared responsibility]

To ensure breadth and mitigate the possibility of missing crucial descriptions of experiences that may enrich constructed themes all 130 profiles were coded. Following Braun and Clarke [35], the entire dataset was coded and by the 79th competence profile, no new codes were created. The coding and construction of themes were primarily done by the first author and discussed and refined by all three authors. This approach can influence the quality and trustworthiness of the constructed themes and thus the final results. An approach including more than one researcher coding the data could potentially increase the internal validity of the themes. However, recurring discussions and peer briefings between the authors and other teaching staff involved in the PBL competence workshops served as external examinations and audits of the research to minimize any bias by the authors [36].

3. Results

The thematic analysis led to the construction of five overarching themes based on students' experiences. Even though the themes project management, communication and reflection are omitted in this analysis, we still found project management to be a vital part of sustaining teamwork. Examples of project management as a way to mitigate potential conflicts are also evident in the students' competence profiles. While reflection is displayed as a potential theme, we argue that the exercise of developing competence profiles is a reflective practice. Fig. 1 shows a conceptualisation of reflective competences running across all three competence domains, which are treated as a specific competence by some students. While such a conception is justified [39, 40], our treatment of reflection concerns students' deliberate response to the experience of teamwork in a PBL environment and how this is conceptualised as competences developed in practice by students. The fives themes are as follows:

- Finding complementary competences.
- Establishing teamwork culture.
- Preventing and managing conflicts.
- Awareness of self and others.
- Shared situational awareness.

Table 3 summarises the competences and key components emphasised by students to be productive for the development of each overarching competence.

The aim is to capture the breadth of described experiences found in each cluster [35] and remain attentive to variations in students' experiences. This means that a theme is not based on quantity but rather on how different excerpts qualitatively expand and contribute to each theme. Each of the five spheres of themes will be elaborated in the following using exemplary direct quotations from students' pseudonymised competence profiles. Furthermore, some excerpts have been translated from Danish into English by the authors for the purpose of dissemination. Excerpts from profiles

Table 3. Summary of competences and components conducive to the development of generic competences emphasised in students' competence profiles

Theme	Components emphasised by students
Finding complementary competences	Competence clarification Defining roles Alignment of expectation* Attentive to personal differences in experience and skills Task allocation Establishing rules and guidelines for teamwork
Establishing and maintaining a culture supporting teamwork	Creating a comfortable work environment Open communication Constructive feedback Differentiation based on personality
Preventing and managing conflicts	Acknowledging peers' perspectives Understanding peers' perspectives Alignment of expectations* Regular meetings (part of project management) Potential for collective and personal growth
Awareness of self and others	Reflexivity Analytical view on differences in personality Critical review of work Multicultural awareness Participation
Shared situational awareness [20]	Formal and informal communication Redistribution of tasks Knowledge sharing Observing and identifying team members' individual strengths Ad hoc role adjustments

* "Alignment of expectations" is a component of two distinct themes, and thus point to an interrelation and coordination of components depending on the application of specific competences.

written in English are extracted directly with only minor alterations to the original text for readability.

3.1 Finding Complementary Competences

The competence profiles show students' various experiences of competence clarification when teams are established. The need for clarification to allocate tasks to the right people has previously been noted [19, 20, 41], and while Bernstein argues that students during their education learn more about less when socialised into a specific discipline [42], students' need for clarification suggests a perception of teams as heterogenic groups comprised by different motivations and competences even within the same educational programme. In the competence profiles, different approaches to accommodate the reciprocal expectation and competences are emphasised, ranging from practical tools to rationales, and arguments are found.

Prior to any activities unfolding in teamwork, there appears to be a need to define competences and roles and align expectations between members involved in the project. The processes involved in efforts aimed at alignment are mostly opaque in the competence profiles and generally related to reaching an agreement while the components of the actual negotiations are undisclosed:

> "How to create a good group work environment, such as using group contracts to set up rules and guidelines for collaboration during a project, which also should ensure that the expectations of everyone for the project are on the same page. Setting up how to manage conflict, where I have competence with holding regular meetings where topics can be suggested anonymously." Student 105.

One student notes that such negotiations can be supported by different tools aimed at establishing profiles of team members, while others write of the 'hidden' process of negotiation:

> "Establish and participate actively in team-based project work by taking into consideration personal differences and skills of each member. Using different tools such as team profiles, business chemistry by Deloitte and the 16 personality types to match co-working partners." Student 3.

> "To get most of the group work, it is important to agree on the team roles. I have not worked with direct delegation of roles but instead focused on understanding the differences between team members and using these in a constructive manner." Student 111.

Several students prioritise reaching agreements on roles and aligning expectations between members, and as shown above, these aspects are important aspects to 'get most out of group work.' Notably, Student 3 address that 'active participation' is related to personal differences and skills, suggesting that engaging actively in PBL requires not only skills but also an attentiveness to how personal differences can be used constructively. This is also noted in a competence profile:

> "Beginning projects with a planning phase, breaking down the project sections into work packages. This is necessary when working with a team with different skillsets and agendas. Assigning work packages to the right people and setting expectations internally with a collaborated plan makes the teamwork fluent and efficient." Student 37.

Again, we find differences in skills and agendas to influence how projects are planned. Assigning specific work packages to 'the right people' enables efficient teamwork while adhering to a collectively agreed upon project plan. What 'efficiency' is in relation to teamwork in PBL is not elaborated in detail. However, several students use adjectives such as efficient and effective to describe how clearly defined roles and distribution of tasks affect their teamwork but not how these influence learning or by what criteria tasks are delegated among peers.

While students addressing roles generally agree of their importance, individual prerequisites for teamwork also come into question when defining roles in a team. In the excerpt below, a student addresses typical roles such as leadership and administrative roles for external communication but also the necessity of accepting that peers may be better equipped for a specific role.

> "The need for clearly defined roles often varies, depending on the team combination. But most teams need some kind of leadership role and an administrative role for the external communication. And this has given me the competences to assume the different roles but also accept that another team member might be more fit to assume the role. The part above about the roles in a team is also depending on the cultural and educational background of the team member. Some might have worked in project teams through their entire education and others might meet project [work] for the first time. Therefore, alignment of expectations is important if the team members have not been collaborating before; this help clarify experience and competences." Student 40.

It is interesting that both cultural background and educational experience co-determine the assignment of roles in a specific combination of students where some are more experienced than others working in project teams. Yet again, alignment of expectations is emphasised, but how this is done in practice is not described.

Finally, a student addresses the degree of heterogeneity in personalities and skills and stresses how a group of similar personalities and skills might hinder progress:

> "Another thing I learned doing group work is that for a group to synergise it can be important to have the group consist of different personalities and skills. A

> group full of 'leaders' might get stuck in discussions, or a group full of analytical people might not see the holistic setting of the project. Therefore, it is important to diversify on personalities in a group.'' Student 31.
>
> ''The experience with how different team dynamics work will help me moving forward in my professional career. I am always looking out for new and interesting aspects within my field to help me become a better engineer.'' Student 49.

Diverse personalities and skills in a group can be important to create synergy. As noted by Student 31, too similar personalities can be a hindrance to move discussions forward or to prevent members from seeing the larger picture of a project. The focus then appears to be how the individual member can contribute to the team as a whole rather than the opposite. Still, the process of such diversification is not described, but it can be argued that the attentiveness to defining roles and clarification of competences needed to perform in the selected roles is pivotal for being able to reflect critically on such decisions.

Experiencing different team dynamics is also deemed to influence the process of becoming a professional engineer. It is not clear if 'new and interesting aspect[s]' are provided by team members, by the individual student or by the supervisor, but one can hope for a combination.

3.2 Establishing and Maintaining a Culture Supporting Teamwork

Developing and sustaining a fruitful environment and culture for the team is a greatly emphasised theme. Generally, students use various terms to describe what others denote as mature communication [47], covering aspects such as articulating ideas, acknowledging peers' perspectives and providing constructive feedback.

> ''We have worked with team building and building a culture where we are open for discussion, and everyone must be heard.'' Student 19.
>
> ''I have also first handedly experienced how important it is to make room for constructive feedback within work teams. It should always be possible to speak your mind but also to realise when your experience or methods are not optimal. The more open-minded the work environment is, the easier it is to make use of constructive feedback, without creating room for disputes.'' Student 44.

Developing a culture of openness with the possibility of delivering constructive feedback to team members is emphasised in many of the students' competence profiles. However, maintaining a culture conducive to teamwork also requires students realising when individual experience or suggested methods are insufficient. It is also clear from the excerpt above (Student 44) that competences accumulated via experiential learning have value when negotiating viable options in project work.

Collaborating with peers seems like a necessity to develop the competences needed to create a rewarding learning environment in teamwork. Working with peers for longer durations presents individual students with a variety of personalities that must engage in the same project. Even though disciplinary contexts and interests set a natural boundary, the different needs of individuals involved in a shared practice must cater to

> ''A nuanced view on how different personalities work in a group setting, and more importantly how to enable each personality type in a group setting. It is important to differentiate between the needs of different personalities, as it can lead to an improved group dynamic and improve the overall output of the group.'' Student 32.

Similarly, maintaining a productive team culture calls for a 'nuanced' view of how people work in a team and also the competences enabling different personalities to improve the output of the team in a productive manner, as well as an understanding of *how* a person works and how to *enable* the specific conditions needed for such work. Competences to cultivate a productive team culture then involve an understanding of both peers, extending beyond that of disciplinary practitioners, and also how to enable a practice. Being exposed to different backgrounds and cultures appears to foster competences to overcome inherent challenges often found in teamwork:

> ''I have worked with people from many different backgrounds and cultures, and I have managed to overcome differences and boundaries to achieve shared objectives. I consider it extremely important to keep a relaxed atmosphere and comfortable work environment along all the process, and plenty of my partners have ended up becoming good friends outside the academic realm.'' Student 82.
>
> ''When forced to work across different teams and team sizes, I have developed in terms of personal skills and adapting to different situations to increase the outcome of the project at hand. This included a steep learning curve when transitioning from the bachelor's to the master's due to an influx of new people to work and collaborate with, all from different backgrounds, approaches, knowledge and past experiences.'' Student 70.

Different backgrounds, cultures and educational experiences among students engaged in teamwork appear to be critical when learning to both establish and maintain a fruitful environment for project work. It is interesting to note how the influx and inclusion of relative newcomers into an existing practice is perceived as a steep learning curve and how backgrounds, approaches, knowledge and experience all influence collaboration (Student 70). Unpacking the student's description, transi-

tioning from a bachelor's to a master's degree is, at least until the peak of the steep curve is reached, disturbed by other students rather than the hitherto 'regular' types. This might indicate that practice during the first 3-year cycle of study becomes routinised or ritualised with regularities concerning both practice and collaborators.

3.3 Preventing and Managing Conflicts

The previous sections have shown the perceived importance of establishing complementary competences, defining roles, task delegation and various focal areas for developing and supporting a conducive culture for project work. While it appears that some agreement is needed in the initial steps of teamwork, conditions aimed at supporting and mitigating conflicts in teamwork are described by students as emerging impediments:

> "Further, getting a successful outcome for the group and therefore the project, it is important to solve misunderstandings and controversy immediately so that these will not be an obstacle further in the project process." Student 28.

According to the excerpt above, controversy should be handled immediately to avoid it becoming obstructive to the process of the project. While misunderstanding and controversy are not necessarily the commonsensical understanding of 'conflict', both are perceived to have a negative influence on an anticipated outcome. More poignantly, we find that a successful outcome is associated not only with a team of people but also with *the* project, where one is a prerequisite for the latter. What makes a project successful can however only be hypothesised. In solving conflicts before they obstruct any process, students describe different strategies and approaches to conflict management:

> "These are competences in how to handle conflicts when they occur in the group work, but also how to prevent the conflicts. I have learned that in most situations the most important thing is to listen and make sure that everyone feels like they have been heard. Furthermore, to prevent conflicts, it is important to always match expectations regarding the work and the approach before the group work begins." Student 50.
>
> "We have handled conflicts in my groups by having weekly meetings where we go through a fixed list of points and where each member gets their own time to talk about each point. The points are time management, teamwork, being late, noise, complaints/constructive feedback, positive feedback. This has helped defuse many conflicts in the groups, as it gives each member a known time and place where they can speak their mind." Student 110.

The first steps of conflict management are taken prior to any conflicts by matching expectations and approaches before teamwork begins. Further, when conflicts occur, acknowledging peers' perspectives is a viable procedure to conflict management. Another option is to include conflict management as a potential point for weekly meetings to give team members the time and place to discuss any frustrating issues. It is notable how project management feeds into features concerning the well-being of the team, transcending the structural competences into the interpersonal.

Conflicts are, however, not only perceived as hurdles but also as potential spaces for learning:

> "I have experience with managing conflicts in a group setting and know different ways of managing conflicts such as properly understanding people's views and finding a way that suits everyone in the group. Furthermore, I have learnt that conflicts are good for a group, as there is potential for improvement, both as a group and as an individual." Student 5.

Much like the other students, a fruitful strategy is one of seeking understanding of divergent perspectives and creating an alignment that suits all members of the team. Moreover, conflicts can be regarded as a potential improvement for both the team and the individual members, implying a constructive approach to conflict management involving personal growth and increased cohesiveness among team members [20].

3.4 Awareness of Self and Others

Engaging in projects for longer durations also indicates a development of reflective practice among students. As seen hitherto, students tend to use peers as reflective subjects from which an identity or position is established. Biesta [43] calls this *uniqueness-as-difference*, but students are also remarkably observant of situations where one form of uniqueness must be replaced with another:

> "I am reflective about my own role in a team, both intuitively but also through an analytical understanding of differences in personality types and learning styles. Though when studying at AAU I often entered a leading role, I know how to fill an empty slot in existing teams, for example in my current employment as study worker in a consulting engineering company." Student 79.
>
> "With the PBL competences, I have learned to be more self-reflecting and aware of the work that I am conducting since we are all a part of a team that is accountable for what each other is conducting. Therefore, throughout the PBL process, I have learned to be more reflective and will review work more critically than before; this will be helpful in the future since it will assist in the process of ensuring that everyone is performing at their best level and to their best competences." Student 21.

Even though students emphasise the allocation of roles and positions early on in the initial stages of project work, we find indications that such posi-

tions are not fixed. Rather, as the excerpts above show, students reflect on internal positions and work being conducted in a project team through both an intuitive and analytical understanding of team members. Further, there seems to be a development of competences to fill a vacant position in existing teams. The shared responsibility among team members is likewise a factor requiring increased reflection and critical evaluation of the work performed by team members. Both excerpts highlight how adaptability and reflection can be transferred to different practices outside the educational realm. Interestingly, the former is focused on individual performance and plasticity, whereas the latter describes reflection and critical evaluation as enablers from a collaborative performance perspective.

Teamwork also affects how dynamics within a project team are perceived and how actions and intentions are interpreted in different ways:

> "Being part of a project team over a period of 2–3 months, I have gained valuable insight into multicultural group dynamics. I've seen and experienced how actions are not necessarily interpreted as the same intention among tea -members and that communication and project alignment are very important." Student 127.

The perceived importance of communication and alignment is again described, but whether these are meant to foster correspondence between intentions and actions is not evident. We can speculate that continued communication regarding the subject matter of a project will lead to a degree of alignment among participants. Working in teams not only provides valuable experiences in team dynamics but may also influence preferences for the criteria on which a team is formed:

> "My preference with group work here is that we were coming from different backgrounds; therefore, we had different opinions about some subjects, and it led us to discussions on which way to go." Student 10.

Here, the students emphasise a preference for collaborating with members coming from different backgrounds and finding common ground from this starting point. This is a prudent example of participation in a Deweyan sense, where 'real' participation is more than merely being together and involves a process of deliberation, in which everyone participating has something at stake. The goal is to develop a shared understanding of where the participants are headed together [44, 49].

3.5 Shared Situational Awareness

Performing teamwork is scaffolded by various activities increasing situational awareness among team members. Like many excerpts found in the sections above, a central element in developing such an awareness is various strata of communication, each related to semantics and properties of specific purposes, such as progress meetings, flow of information and timely delegation of tasks:

> "I have experienced the importance of a progress meeting where it can be discussed how far in the work process each group member is and if it is necessary to redistribute tasks between the members in the group in order to complete a well-executed project. The progress meetings are also a great way for the group members to share newly gained knowledge and experiences." Student 50.
>
> "I find it [to be] important with regular and open communication between group members, both in the form of structured meetings and informal communication. I like to have an overview of other team members' progress and a continuous communication of how preliminary results affect other aspects of the project. This also makes the group more resilient in terms of detecting errors since strategies and results will be discussed between members." Student 74.

Mutual awareness of team members' progress with respect to tasks is generally perceived as important. Formal and structured meetings serve as a space for discussing and sharing knowledge, for the potential redistribution of tasks and also to assess how preliminary results influence the remains of a project. Notably, discussing strategies and results makes the team more resilient in detecting errors. In other words, it appears that the mutual engagement of team members transcends the potential resilience of the individual if left to one's own devices. Further, it is interesting to note how the team is implicitly understood as a life form with the use of the psychological and behavioural attribute 'resilience', often associated with the individual student [45], suggesting the team is perceived as more than a fleeting semester-long cluster of peers working together and takes a form of being.

Collaborating with peers not only necessitates some division of roles, as seen previously, but also affords students the opportunity to observe and identify the strengths of individual team members. Some students emphasise a specific position or role on a team as a condition for such observations:

> "I have much experience with a leader role, and therefore I have learned to observe and identify teammates' individual strengths and delegate work accordingly. This could be identifying that one group member is very detail-minded, and I have therefore made sure they are working on parts of the project where detail is needed." Student 55.

In the excerpt above, there appears to be hieratical organisation of the team, where one person leads and delegates tasks to the remaining team members. Other students observe the same competence devel-

opment, but from other perspectives, from previous colleagues and from reflective practice:

> "During the last years of my education, I have gained the skills needed to coordinate a project to ensure that each group member gives the best of themselves to achieve the common goal. These skills were acquired by observing the behaviours that made previous work colleagues show great leadership capabilities." Student 82.

> "By working with different people in different groups, I have learned to possess different roles in the group interaction. To be able to possess different roles is a very important ability, as it makes it easier to adjust the group work and take on the work or the role needed to complete a good project." Student 50.

It is striking that skills needed to coordinate a project develop during the last years of education (Student 82) and that these skills were acquired by watching the behaviour of those deemed more proficient. How these observations of behaviour are internalised and practised by the student is not described further, but it is worth noting that the learning environment at least provides a testing ground for the student to emulate such behaviours. Working with different people also promotes students learning to assume different roles on a team and to adjust to the teamwork and roles needed to complete a project. While students tend to emphasise role clarification, Student 50 remarked that on-the-fly adjustments in roles indeed occurs. This indicates that practising teamwork in PBL is less stable than students perhaps anticipate when initiating teamwork by clarifying expectations and dividing roles.

4. Discussion

The thematic analysis of students' PBL competence profiles resulted in the construction of five themes: finding complementary competences, establishing teamwork culture, managing conflicts, awareness of self and others and situational awareness. It is striking to find communication as the enabler of competent enactment in each of the five constructed competences. Communication requires one to preconceive and model utterances to potential recipients in an anticipatory fashion [44]. Consequently, students appear to become increasingly reflexive and aware of other people partaking in their practice. The social conditions of a PBL environment then serve both theoretical perspectives found in foundational learning principles [26] and practical notions of experiential learning. Whereas the experiential is often attributed to the activation of prior experiences [27], the social serves as both a space for negotiating and constructing knowledge as well as a place of 'objects' and 'subjects' for reflection. Excerpts show how students 'use' others to position themselves in relation to them, i.e. role allocation, observations of team members, mature communication. Following Dewey [27], the social and collaborative environment has 'widened the external conditions for subsequent learning' for students in which communication is a central, almost bordering ontological position [43]. The generic communication and teamwork competences are thus empowering the practice of disciplinary knowledge and skills within a specific context [13]. Following this enabling influence, 'communicative competences' and 'teamwork competences' are then not quite suitable concepts to capture what we will consider as competences scaffolding the *social* activities central in both. Rather, it could be argued that teamwork is communicative practice using various semiotic resources, and the competences involved in it are communicative. Sign and signifiers gain and give meaning to the context and experience in which they are produced and vice versa [34]. More potently, communication allows students to become '[. . .] cognizant of the common end and all interested in it so that they regulated their specific activity in view of it, then they would form a community' rather a group of students [44, p. 5].

The positioning of the *I* in the relation to the group is surprising to us. Rather than an individualistic approach, the collectively oriented attitudes of students is apparent. Although many of the students' descriptions of competences in situ are noticeably comparable to those found in the supplied material, events of subject-ness found in the profiles stand out in comparison. Several students describe how positions and roles change as a response to ensure the continuity of a project, and how changes in task allocation can be necessary to increase the performance of a team. Planning then becomes a question of anticipatory competences developed in a holistic continuity of theory and practice rather than in broken segments of applying theory to practice [46]. However, between the educational programmes some discrepancies exist in the emphasis on the individual positioning and the collective efforts of the team. One prudent example is role allocation, where most students from one department write of being team leaders and bringing 'home the project', whereas such positions are more fluidly depicted by students from the remaining two. We can only hypothesise, but individual vocational aspects are more prevalent in the former students' descriptions, and the differences can be attributed to a close collaboration with companies throughout the education, instruction and framing of the workshop and the individual student or a combination. Qualifying the

perspectives exemplified in the profiles would require a different research approach than the one applied in this paper and involve several actors and not only students. Still, there is a consensus among students of the importance of forming and maintaining a functional team, and students' attitudes gravitate towards emphasising the acceptance of other people as pivotal to meeting this end. Whether this is based on considerations concerning the performance of a team or personal development based in formative aspects of education known from the German and Nordic Bildung tradition would, from our perspective, be worthwhile to investigate.

Pedagogically the thematic analysis and subsequent placement of communication as central to enabling various parts of teamwork requires careful framing of communicative competences. As we have noted, simply stating 'communicative competences' without considering what contexts such competences give and gain meaning results in a mere nodal point [47], either devoid of value or malleable enough to cause anything rendering such conceptualisations to be meaningless. Knowledge of what communicative competences students need to cater to specific aspects of teamwork has been highlighted previously [13, 20], and such knowledge of the various components of teamwork can serve as sensible examples adding 'value' to communicative practices. According to Woollacot [13], who quotes a phenomenographic study of generic graduate attributes by Barrie [48], four categories of generic attributes emerge: precursor skills functioning as a backdrop to disciplinary competences in tertiary education, complementary skills standing on their own and not directly linked to disciplinary knowledge, translation skills enabling the application of disciplinary knowledge and skills that are explicitly linked to disciplinary knowledge in a curriculum, and finally, enabling skills recognised as interwoven and empowering parts of disciplinary skills and knowledge. The categories identified by Barrie [48] also hint at the multiple interpretations of the *generic* aspects, ranging from competences not directly related to any discipline, whereas the fifth category suggests that generic attributes are closely tied to a disciplinary context and professional practice. Hence, concepts such as 'teamwork', 'collaboration' and 'communication' may need further qualification when used across disciplines as these are coupled to a specific educational or professional practice.

4.1 Limitation of Research

The two-fold function and framing of the profiles may influence the results of the thematic analysis. Noted by Prior [49], documents serve specific functions giving and gaining meaning from the social context and actors in which they are situated. Functioning as assignments, students might be more reluctant to write from a personal perspective and primarily provide more superficial descriptions not involving the important affective and behavioural dimensions in reflection [30]. Hence, the attitudinal perspective influencing competence at work may not become explicit for students. As students needed to write and pass the competence profile to attend their project exams, some students might have taken a less reflective position and written what was needed to pass. In some instances, the students' profiles had similar formulations and foci. Other students have used the profiles as an opportunity to reflect on their PBL practice and competence development from a more attitudinal and personal perspective. While both positions will influence the results of a thematic analysis focused on the quantity of similar codes or excerpts, our focus on breadth in constructing the themes ought to show the diversity within the themes.

Even though personal dispositions appear central for PBL competences, they are developed within the specific framing of education with peers coming to know each very well over the course of years through extensive project work. How students' attitudinal dispositions act as enablers in professional contexts with changing colleges and environments needs more research. Additionally, we suggest that phenomenologically oriented research or longitudinal research based on students' unaided conceptualisation of teamwork competences may yield further results related to our understanding of the development of teamwork within engineering education. Furthermore, we find that additional research into the stratification of communicative practices found in teamwork is needed and that results may promote a more holistic view of the communicative mechanisms in teamwork for students. Our final remark is one of pleasant surprise concerning students' level of reflection and conceptualisation of their teamwork competences as well as their increased interest in student reflections as an ongoing part of their practice in a less formalised setting and how these competences are articulated in such a process.

5. Conclusion

The thematic analysis of students' written reflections concerning generic competences developed in PBL resulted in five themes, each covering different competences and components emphasised by students to create and maintain a fruitful environment for teamwork. The analysis showed students developing both generic competences and personal atti-

tudes that allow for events of subject-ness, in which the student is positioned in relation to a team and its members. Though students were reflecting on their generic competences development, it was surprising to find personal attitudinal dispositions intertwined with descriptions of generic competences. For most students, competences do then not only concern knowledge and skills put in practice in unknown situations, but they are entangled with attitudinal dispositions that enable such engagement. This is done in several ways, such as finding complementary competences and creating a culture supporting teamwork through which students, in our view, try to anticipate potential directions for a project. The mutual direction and allocation of tasks are not fixed but malleable and fluid, affording timely adjustments of roles and flexibility. To succeed in such open-ended processes, students address a need for a sense of awareness of team members and a shared situational awareness of tasks and the situation of the team. It appears that students are acutely aware of individuals on the team, how each can contribute to the team and what competences and components are needed to achieve such ends.

Students' competence profiles emphasise reflexivity as an important attribute when collaborating and highlight mature communication as a cornerstone in maintaining positive team culture. The thematic analysis also shows how communication and teamwork are intertwined concepts, and the competences to do both empower the disciplinary competences. The social and collaborative environment in PBL is central to promoting communicative and teamwork competences and attitudes towards teamwork, suggesting that transactions between students and scaffolding paedagogical principles are of great importance in developing students' generic competences. From a paedagogical perspective, our analysis can aid in both framing and planning learning activities that cater more specifically to components presented in Table 3. As an example, activities aimed at developing shared situational awareness could involve supervised and planned interventions altering the course of students' projects to elicit a situation requiring students to reframe parts of a project.

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