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Teamwork dynamics in the context of large-size software development courses

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Abstract

Background Effectively facilitating teamwork experiences, particularly in the context of large-size courses, is difficult to implement. This study seeks to address the challenges of implementing effective teamwork experiences in large courses. This study integrated teamwork pedagogy to facilitate a semester-long project in the context of a large-size class comprising 118 students organized into 26 teams. The data for this study were collected from two online teamwork sessions when teams collaborated and self-recorded during the in-class time. The video recordings were qualitatively analyzed to identify patterns in team dynamics processes through visualizations. The study aims to provide insights into the different ways team members engaged in team dynamics processes during different phases of the semester.

Results Findings suggest that members of teams were mostly active and passive during meetings and less constructive and interactive in their engagement. Team members mainly engaged in communication, team orientation, and feedback behaviors. Over time, team members' interactions with one another remained about the same, with feedback behaviors tending to diminish and coordination behaviors staying about the same or slightly increasing over time.

Conclusion The implications of this study extend to both practice and theory. Practically, combining cooperative learning and scrum practices enabled a blend of collaborative and cooperative work, which suggests providing teams with tools and structures to coordinate teamwork processes and promote interaction among team members. From a theoretical perspective, this study contributes to the understanding of temporal aspects of teamwork dynamics by examining how team interactions evolve during working sessions at different points in time. Overall, this research provides valuable insights for educators, practitioners, and researchers aiming to enhance teamwork experiences in large courses, particularly in software development disciplines.

Keywords Teamwork pedagogy, Large-size course, Software development, Undergraduate education, Cooperative learning, Student engagement, Team dynamics, Scrum, Project management

Introduction

Organizations and governments expect recent graduates from higher education institutions to be productive members and leaders of teams (Lowden et al., 2011). As a response to this expectation, instructors in higher education have integrated teamwork into their teaching practice (i.e., Chen et al., 2021). However, effectively facilitating teamwork experiences, particularly in the context of large-size courses, is difficult to implement (Allen & Tanner, 2005; Faust & Paulson, 1998). Part of the challenges relate to (a) previous negative experiences

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among team members influencing their perceptions about teamwork (Felder & Brent, 2007); (b) overall management of teams, monitoring potential negative behaviors, and conflict resolution (Bolton, 1999); (c) individual and team assessments that balance the recognition of individual efforts and team dynamics with the collective outcome of the team being difficult to implement (Freeman & McKenzie, 2014); (d) the need for additional teaching assistant support and their training (Sargent et al., 2009), among others. Thus, research has identified the need for improved strategies for teaching teamwork skills in higher education, specifically in engineering and computing education (Paoletti et al., 2020; Woods et al., 2000).

A systematic literature review on teamwork in educational settings reported on a range of instructional strategies used to teach teamwork knowledge and relevant skills (Riebe et al., 2016). Some of these instructional strategies include teaching collaborative and cooperative teamwork (Riebe et al., 2016) and introducing team-training tools for students (Rapp & Mathieu, 2007). However, scant research reporting on the implementation of teamwork pedagogies in large classes has also reported a lack of success (Alexander, 2006; Danko & Duarte, 2009). Furthermore, although instructors in higher education have transitioned to implementing active learning pedagogies to facilitate teamwork, research assessing these initiatives has lagged (Borrego et al., 2013). This study, conducted as part of a computing course, has the dual goal of (a) implementing and validating the integration of teamwork pedagogy to facilitate a semester-long project in the context of a large-size class and (b) characterizing team dynamics resulting from the teamwork orchestration of the semester-long project. Specifically, the research questions are: (RQ1) What are the levels of team members' interactions in the context of teamwork sessions? (RQ2) How do these interactions change over time? And (RQ3) What patterns emerge among teams regarding their communication and coordination processes?

Teamwork in educational settings

It is widely accepted that students learn more effectively while collaborating as they can share ideas, work collaboratively to solve problems, and learn from each other (Pattanpichet, 2011). Such interactions thereby enhance the learning performance of the group as well as that of the individuals (Huang et al., 2012; Wang & Hwang, 2012). Specifically, research in computing and engineering education has identified certain attributes that contribute to more effective educational teams. Such attributes include (a) shared goals and values, (b) commitment to team success, (c) motivation, (d) interpersonal skills, (e) open and effective communication, (f) constructive feedback, (g) ideal team composition, (h) leadership, (i) accountability, (j) interdependence, and (k) adherence to team processes and performance (Chowdhury & Murzi, 2019). Although these characteristics have been observed in effective teams, it is also important to identify ways to develop them in terms of pedagogical approaches and specific training mechanisms. Developing teamwork skills is particularly important since research has identified that teamwork training is a necessary precursor to assigning students complex team-based projects (Lingard & Barkataki, 2011; Riebe et al., 2016). However, engineering and computing education instructors have lacked consensus on how to effectively teach teamwork skills (Sheridan et al., 2015). This lack of consensus can be attributed to several factors. Engineering and computing education instructors come from diverse backgrounds, experiences, and educational philosophies. They may have different criteria for what constitutes successful teamwork (Chowdhury & Murzi, 2019), resulting in varying beliefs about teamwork's importance and teaching methods. Moreover, many of these instructors may have limited experience operating in teams themselves, and they may lack training, guidance, and tools to effectively teach and assess teamwork skills in their students (Lingard & Barkataki, 2011).

By adopting a situated learning perspective, engineering and computing instructors can create learning environments where all students share a common objective to implement an activity that they all identified as significant for their learning (Lave & Wenger, 1991). This situated learning perspective can be achieved by implementing teamwork pedagogy. Teamwork pedagogy relates to an instructional intervention that attempts to implement practices into the process of teaching students, which assists in the growth of student's communication skills by increasing the frequency of dynamic interactions between students within a team while executing their project (Riebe et al., 2016). Teamwork pedagogy steps away from the product and results-oriented approaches by focusing more on the psychological and communicative capabilities of the students, such as collaborative problem solving and accountability (Riebe et al., 2016). Research on teamwork pedagogy in higher education has documented different instructional strategies that can develop teamwork skills (Riebe et al., 2016). Some of the promising teaching strategies include introducing collaborative and cooperative learning, team-training tools like simulations, role-playing, and self and peer assessments (Riebe et al., 2016).

Problem-based learning and cooperative learning are two traditional teamwork pedagogical approaches in computing and engineering education. Problem-based learning is a student-centered teaching approach that

aims for students to increase their knowledge of a subject area by collaborating with other students to solve a given problem, generally open-ended (Chen et al., 2021). This approach allows the students to take the reins of their learning, with the instructor guiding them once the problem is presented to them. In order to create an applicable solution, students must think and analyze critically, building upon their previous knowledge while internalizing new relevant subject knowledge (Chen et al., 2021). Consequently, this also places the burden of motivation on the students since they must take the initiative to create these intellectual connections and apply them to the problem at hand.

While problem-based learning encourages student learning by internalizing and applying material, cooperative learning encourages students' engagement (personally and interpersonally) within their group to achieve their goals (Johnson et al., 2014). Cooperative learning operates on five core principles: positive interdependence, promotive internal interactions, individual accountability, training of interpersonal skills, and group processing (Felder & Brent, 2007). Positive interdependence is the understanding that each individual's efforts within a group are key factors to the project's overall success. Promotive internal interactions are the constant positive communications between group members; these can be in the form of praise, feedback, and/or offers of assistance. Individual accountability is each group member's understanding of their responsibilities and how they contribute to the overall project goals. Interpersonal skills are the individual social skills developed by each group member that assist in the execution of the project (e.g., conflict handling skills, verbal and non-verbal communication skills, etc.). Group processing is the strategy that a group has set forth in order to facilitate effective project execution.

Conceptual framework

Engineering education researchers have emphasized the need to apply industrial and organizational psychology findings to inform engineering education research (Borrego et al., 2013). A substantial body of research in organizational psychology and behavior has emphasized the critical role of mediating mechanisms associated with effective teams (Mathieu et al., 2019). These mediating mechanisms refer to team processes and dynamics where team members' interdependent acts are directed towards organizing taskwork to achieve collective goals by converting inputs to outputs (Marks et al., 2001). Team dynamics play a critical role in a team's ability to function effectively (Buffinton et al., 2002). Team dynamics refers to the changing relationships in team-level phenomena (Collins et al., 2016). Specifically, it focuses on the interactions among team members that regulate overall team performance (Dorairaj et al., 2012). A framework that has been used as a lens to study teamwork interactions and group behavior in education settings is the Interactive–Constructive–Active–Passive (ICAP) framework (e.g., Anwar & Menekse, 2020; Hodges, 2018). The ICAP framework was initially proposed by Chi and Wylie (2014) to describe four different categories of engagement or interactions among learners and the learning materials according to overt behaviors in the learning process (Chi & Wylie, 2014). The highest level of interaction happens in the interactive category (Chi & Wylie, 2014), where learners significantly and constructively interact with other team members. For this study, being interactive meant that students were engaged in conversation turn-taking, performing actions such as debating, brainstorming, and discussing. The next level of interaction occurs in the constructive category, where learners individually produce ideas or generate outcomes related to the task (Chi & Wylie, 2014). For this study, being constructive involved actions such as asking questions, taking notes, verbally comparing notes, drawing, or writing. The level of active is characterized by students engaging with the learning material actively but not constructively (Chi & Wylie, 2014), involving some form of overt motoric action or physical manipulation, but without producing new ideas.

Team dynamics in educational settings has also been theorized within the context of communication and coordination processes, among other variations in team outcomes resulting from environmental contingencies (Collins et al., 2016). For instance, it has been identified that more collaboration within a team often results in higher academic performance (Menekse et al., 2017). Specifically, team dynamics can be characterized as positive when team members work collectively, support each other, contribute, and listen to ideas. Team dynamics can also be characterized as negative when team members disrupt work processes, disengage, or generate negative conflicts inside the team. An integrative characterization of communication and coordination processes within teams is the model presented by Dickinson and McIntyre (1997). This model has been extensively used to characterize team processes that may lead to team performance (e.g., Cortez et al., 2009; Jaiswal et al., 2022; Porter et al., 2010). The model characterizes the seven core components of teamwork: communication, team orientation, team leadership, monitoring, feedback, backup, and coordination. Team orientation includes team members' attitudes towards the team and other team members. Team leadership refers to the structure and direction that a leading team member can give to the group. Communication is the exchange of information between team

members. Monitoring refers to the observation and awareness of the tasks and performance of other team members. Feedback relates to giving or seeking feedback from other team members. Backup involves helping other team members perform a task. And coordination refers to the way team members respond to the behavior of others executing the team activities (Dickinson & McIntyre, 1997).

The implications of the conceptual framework for this study relate to characterizing team dynamics in terms of students' patterns of interactions and communication and coordination processes as a result of teamwork orchestration of a semester-long project guided by teamwork pedagogy. Thus, in our analysis, the first step was to operationalize the construct of team dynamics. According to our theoretical framework, the team dynamics construct involves patterns of interactions and coordination processes among team members that regulate overall team performance (Collins et al., 2016; Dorairaj et al., 2012). Figure 1 depicts the conceptual framework that showcases our characterization of team dynamics in terms of patterns of interactions, operationalized by Chi and Wylie's ICAP framework, and communication and coordination processes, operationalized by Dickinson and McIntyre's integrative model.

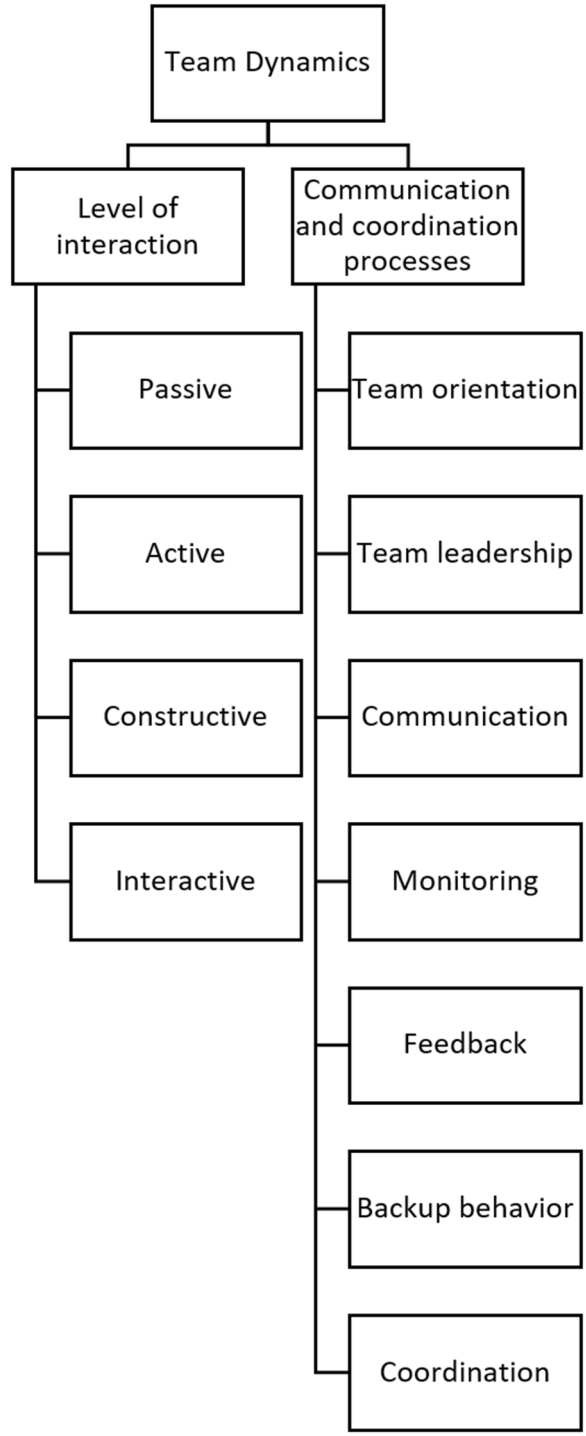

Fig. 1 Conceptual framework depicting the operationalization of team dynamics

Methods

This descriptive study characterized the team dynamics within the software development teams in the context described in the 'Content and Course Design' section below. Guided by our conceptual framework, we first characterized the level of interactions among the members of each team (RQ1). Then, we compared the level of interaction between the first and the second teamwork sessions and grouped teams according to those changes (RQ2). Finally, within the identified groups, we characterized their team dynamics concerning their communication and coordination processes. Data were collected in the Fall of 2021 when the course offering resumed a fully in-person class format after the COVID-19 pandemic.

Context and course design

The context of this study was a second-year systems analysis and design course at a Midwestern university in the USA. The course is required for undergraduate students pursuing software engineering, cybersecurity, and network engineering majors. The course design followed a situated learning perspective to fulfill the course objectives and the implementation of those through active learning strategies. Course objectives aimed to develop skills used by software developers or systems analysts to model requirements, perform a cost–benefit analysis, and then construct and model an acceptable design to implement a successful system solution in the form of a functional prototype. Specifically, students worked in teams of four members. The teams were formed following two steps. The first step consisted of students

proposing names of peers they wanted to work with. Each student suggested working with one or two students from the course by submitting the name of either someone they worked with previously or a friend, or no option was submitted. Then, a second step involved the course teaching assistant forming the final teams of four members, trying to honor as much as possible all students' requests.

The project consisted of implementing a software development solution for a case study whose deliverables consisted of design specification documentation, a functional prototype, a usability evaluation of their prototype, and a sales presentation of a prototype. The project was organized into (a) four milestones for producing the documentation of the system specification and (b) five product deliverables for implementing the functional prototype, herein called sprint (refer to Appendix for a timeline).

The course format consisted of a weekly 3-h lecture with no laboratory portion. The course used an active learning format where students were given the opportunity to work in teams during lecture time (and outside of the lecture). The lecture was offered on a Tuesday/Thursday 75-min session. During the Tuesday session, the instructor introduced new concepts and techniques (e.g., strategies for documenting requirements, diagramming techniques, elements of prototype valuation, etc.), provided practice of those concepts within the teams, and followed with feedback. During the Thursday session, specifics of the project were discussed (e.g., indications for milestones), and students had most of the class period to work in teams to make progress on their project.

To manage the project, students were introduced to scrum practices, which are commonly used in industry to manage software development projects (Jurado-Navas & Munoz-Luna, 2017; Marek et al., 2021; Sharma & Hasteer, 2016). Scrum combines technical, communication, and teamwork skills to support development teams in delivering quality software products (Rising & Janoff, 2000). Scrum practices are organized into roles, artifacts, and events. The three most important roles are the development team, the product owner, and the Scrum master. (1) Development team, performed by teams as a unit, and together being responsible for creating the product. (2) Product owner, rotated by all team members throughout each sprint, was responsible for keeping the Gantt chart and product backlog for a particular sprint. (3) Scrum master, also rotated by each team member, was responsible for supporting the development team, enabling communication during meetings, and facilitating conflict resolution (Magana et al., 2018). Scrum artifacts consisted of the project documentation, called product and sprint backlogs, and the actual prototype, called product increment. Finally, the events consisted of sprint planning, sprint increments, and retrospectives. Sprint planning occurred weekly during class time. Project prototype submissions were the actual sprint increments, delivered every 1 or 2 weeks, as shown in Appendix. In addition, within each major delivery students also reflected on the process as a team by performing a team retrospective. The team reflected on the previous deliverable and identified and agreed on continuous process improvement actions.

Regarding assessment methods, 50% of the final grade for the course was assessed with the project score. The project scoring included the prototype, the documentation of the project solution, and the individual project contribution. Students also performed a self and peer evaluation and submitted a contribution chart together, consisting of 10% of the final grade. Class participation consisted of 15% of the final grade, and this was graded with submissions evidencing class participation. There were two term exams that evaluated students' abilities to document and model requirements of a system consisting of 15% of the final grade. The remaining final grade consisted of quizzes (8%) and other required project submissions such as team contracts (1%) and the required videos used as the data collection method (1%).

The course was orchestrated by implementing cooperative learning (Johnson, Johnson, & Smith, 1998) as a pedagogical approach to orchestrate a semester-long project. Cooperative learning aligns well with scrum practices as both promote teamwork interaction, planning, reflective practices, and a combination of individual and group work (Magana et al., 2018). Specifically, the principle of positive interdependence was implemented by establishing a clear goal for students to accomplish. This was achieved by defining specific milestones and submissions for the students to complete throughout the semester, as well as, by having students plan the project deliverables and roles using a Gantt chart. The principle of individual and group accountability was achieved by having two-thirds of the project graded as a team and one-third of the project graded individually. The principle of interpersonal and small group skills was facilitated by discussing and reflecting on effective teamwork skills, facilitating conflict resolution training, and signing team contracts at the beginning of the semester to help students establish specific rules, roles, and coordination processes. The principle of face-to-face promotive interaction was mainly facilitated by devoting in-class time for teams to work on their projects. Specifically, the Tuesday lecture was devoted to introducing new concepts and skills along with practice activities, while the Thursday lecture was devoted to teamwork, where students applied the learned skills to their projects. Finally, the principle of group

processing was facilitated by having students reflect on their team processes and submit these team-based reflections along with each of the four project milestone submissions. Additional details of how the class was orchestrated and implemented can be found in our previous work (Magana et al., 2018, 2022).

Participants

Participants for this study included 118 s-year undergraduate students, all of them taking the course for the first time, organized into 26 teams of four members. According to institutional data, there were 29 female and 89 male students. Fifty-seven students reported their ethnicity as White, 27 as International, 13 as Asian, 10 as two or more races, six as Black or African American, three as Hispanic or Latino, and two as unknown. Students' ages ranged from 18 to 26 years old, with an average of 20 years of age. All students were proficient in the English language (i.e., students from non-English-speaking countries had to submit proof of English proficiency to be admitted to the program) and had already completed at least one year of undergraduate instruction in English at the same institution. Previous preparation for this course included a first-year course focused on leadership, teamwork, and globalization and an introductory first-year course in systems analysis and design. As part of these courses, students (a) developed solutions applying the principles of human-centered design, (b) communicated effectively and worked in teams, and (c) applied systems development techniques for the design, construction, and testing of an information system.

Procedures and data collection methods

Five online teamwork sessions were scheduled throughout the semester (weeks 3, 4, 7, 8, and 10). The purpose of the first session was for students to get used to the Microsoft Teams platform. In that first session, students joined their respective team channels and discussed and signed their team contracts. The following online teamwork sessions were scheduled right before a major deadline. Also, the last 2 weeks of the semester were facilitated fully online, as students would be mainly working on completing their final project submissions during that time.

The data for this study were collected from the second and fifth online teamwork sessions, which took place in the fourth and tenth weeks of classes, as shown in Appendix. For these two sessions, students collaborated online and self-recorded their teamwork sessions using the features provided by the collaboration platform. During the first online teamwork recorded session, students worked on preparing the submission of the first project milestone, Milestone 1. During the second teamwork recorded session, students worked on Milestone 3. Each of the recordings had an average duration of 40 min. Of the 26 teams, recordings of 20 teams were used for the analysis of the first session, and recordings of 15 teams were used for the analysis of the second session. The missing recordings were excluded from analyses due to bad video or audio quality.

Data analysis and scoring methods

The data analysis methods scrutinized the data in divergent forms to approach the three research questions. We initiated the analysis by first identifying the level of interactions among the members of each team, thus approaching RQ1. For this initial level of analysis, it was necessary to characterize the level of interaction among team members. For this, we used the elements of the ICAP model as described in our conceptual framework. Specifically, being active involved actions such as taking notes, agreeing with other members, providing suggestions, and quoting project indications. The last level is related to the *passive* category involving behaviors where the student mostly receives information from the material or task without engaging with it (Chi & Wylie, 2014). For this study, being passive mainly involved listening or nodding to group members without taking notes. We also coded for instances where students were disengaged, for instance, leaving the group meetings mid-way, getting distracted with technology, or not paying attention. Finally, we also characterized instances of disruptive behavior such as yelling, ignoring group members, overpowering conversations, or being late to the meetings.

The analysis of the videos was initiated by focusing on each team member individually and their level of participation according to the ICAP framework (including disengagement and disruptive behavior). Individual student behaviors were analyzed during every 2-min interval of a session and then coded into one category per time interval. Category timelines were created for each member of the team. Then, weights were assigned based on the level of interaction. Interactive was assigned the highest weight (2), followed by constructive (1.5), active (1), and passive (0.5). Cognitively disengaged and disruptive behaviors demonstrated no engagement; therefore, they were given a score of negative one (−1). Using the weights, an average team score was calculated for each 2-min interval. The next step consisted of visualizing the interactions over time utilizing the average scores for each of the teams.

The next step in the analysis consisted of identifying changes in the levels of interaction across sessions over time, thus focusing on RQ2. For this, we compared the level of interaction between the first and the second teamwork sessions and grouped teams according to those changes. Only 12 out of 26 teams' video recordings

were coded for both sessions. The other teams' recordings were not used and, therefore, not coded because they were either incomplete, had absentees, or did not have any visuals (no cameras on). For these 12 teams, we calculated a Total Interaction Score (TIS) based on the weights assigned for RQ1. For example, students in team 15 during session 1 were interactive two times, active 30 times, passive 25 times, cognitively disengaged three times, and were not constructive or disruptive throughout the session. Thus:

$$\text{TIS} = iw_1 + cw_2 + aw_3 + pw_4 + gw_5 + dw_6$$

where TIS = Total Interaction Score, i = Frequency of interactive behavior, c = Frequency of constructive behavior, a = Frequency of active behavior, p = Frequency of passive behavior, g = Frequency of cognitively disengaged behavior, d = Frequency of disruptive behavior, w_1 = Weight assigned to interactive behavior, w_2 = Weight assigned to constructive behavior, w_3 = Weight assigned to active behavior, w_4 = Weight assigned to passive behavior, w_5 = Weight assigned to cognitively disengaged behavior and w_6 = Weight assigned to disruptive behavior.

Substituting values in the equation,

$$\begin{aligned}\text{TIS} = &(2 \times 2) + (0 \times 1.5) + (30 \times 1)\\ &+ (25 \times 0.5) + (3 \times (-1))\\ &+ (0 \times (-1)) = 43.5\end{aligned}$$

We then divided the TIS by the number of time intervals in that session. This gave us the engagement of the team per time interval. The adjustment on the engagement per time interval, instead of the raw total engagement score, was necessary because otherwise, teams with longer sessions would end up having an overall higher score even when they were less engaged. This adjustment also helped us to compare the two sessions when the recordings for the same team for the two sessions had different durations. For instance, considering the example of team 15, the duration of the first recording was 30 min or 15 2-min intervals, giving us an interval score of 43.5/15 = 2.9. We performed the same calculations for the 12 teams and both sessions per team. Finally, we calculated each team's percent change in score from session 1 to session 2. We then visualized the percent change in a bar graph, revealing the patterns that allowed us to group the teams based on the change in their level of interaction between session 1 and session 2.

Finally, to approach RQ3, we delved deeper into the groups identified in RQ2. Specifically for each group, we characterized their team dynamics concerning their communication and coordination processes following the Dickinson and McIntyre model (1997). Specifically, communication was coded when we observed instances of asking or rephrasing questions, discussions among team members regarding course materials, and casual conversations and socialization processes. Instances of teamwork orientation were coded when attitudes, positive or negative, were enacted by the students. For instance, expressions of frustration, dissatisfaction, tiredness, eye-rolling, and ignoring group members were considered negative attitudes. Behaviors such as providing assistance, reassurance, and praise were coded as positive attitudes. Regarding team leadership, behaviors were coded when conversations focused on deciding roles and tasks, explanations and guidance by team members, and listening to indications or concerns. Monitoring was enacted by team members making references to each other's progress and tasks to complete next, and backup behavior was coded when team members helped each other or volunteered to fill in. Behaviors representing feedback included responding to others' requests, accepting suggestions, seeking and offering clarifications, and asking for help. Finally, coordination processes included planning behaviors regarding a task or a meeting. Double coding was allowed for the seven categories of the Dickinson and McIntyre model (1997) because team members could exhibit more than one teamwork process in the 2-min interval. Since the Dickinson and McIntyre model does not follow a hierarchy of behaviors, all the codes were assigned a weight of a positive one, except for team orientation, which could include negative or positive attitudes. Total counts for each of the behaviors were then tabulated for each team and for each team member within a team. After normalizing the counts to determine the percentage of behaviors enacted by each team and contributing team members for such behaviors, visualizations were created for further interpretation.

Results

The study results are organized into three sub-sections aligned with the three research questions.

Characterizing team members' levels of interaction

Overall, during the first meeting session, team members were mostly active or passive (refer to Fig. 2). On a few occasions, members of some teams were constructive or interactive. On rare occasions, students were disengaged. Similarly, during the second meeting sessions, team members exhibited active or passive behaviors on several occasions, constructive or interactive behaviors on a few occasions, and disruptive and disengaged behaviors on rare occasions.

Generally, for the few occasions where teams were constructive or interactive, members were often discussing the meanings associated with elements of their project

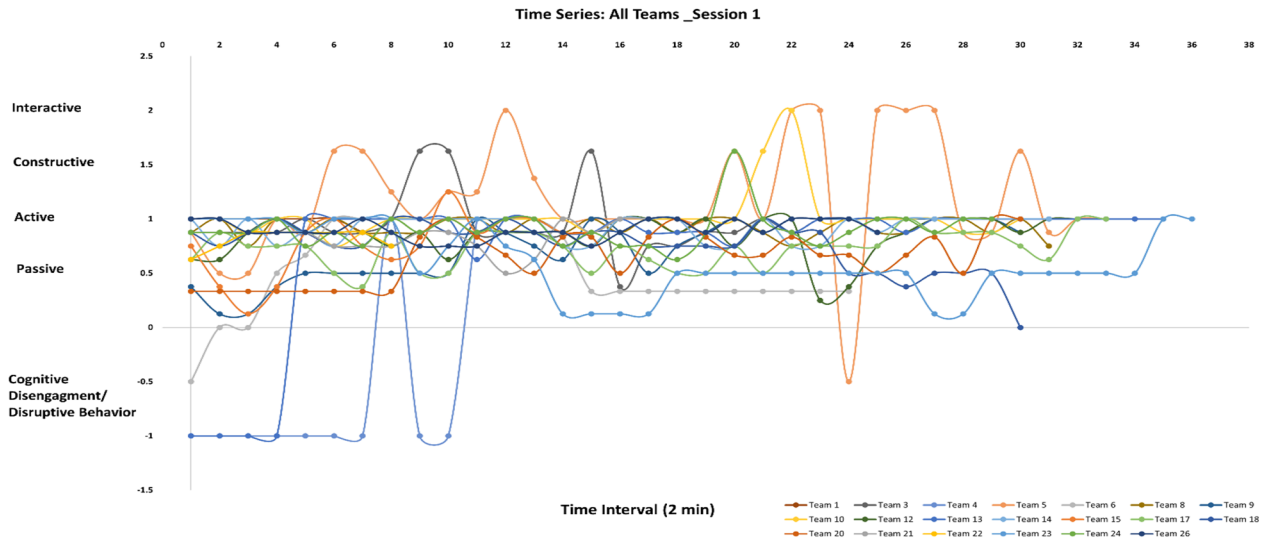

Fig. 2 Team members' collective level of interactions during teamwork session one

(especially diagrams modeling aspects of the system) and critiquing one another's part of the deliverables that they all agreed upon as a team. For example, within the 16th–18th minute of their first meeting session, members of team 3 were being constructive and interactive by discussing a diagram, the meanings of the actors interacting with the system, referring to previous examples assigned by the instructor, and making decisions about what entities and components to include and exclude. Within the 28th–30th minute of the same session, the team 3 members referred to the sample assignment provided by their instructor and critiqued the new examples one of their colleagues had created, thereby exhibiting interactive behavior.

Similar observations were made for the behaviors of team members in session two (refer to Fig. 3). For instance, during the 18th–20th minute interval, students of team 7 were deliberating on the information to include in the context diagram. These same students, during the 44th–46th minute, discussed, again, statements to include in their context diagrams. On rare occasions when students were disengaged, their cameras were off, they were engaged in discussions that created an environment for learning about one another, or they waited for others to join the meeting.

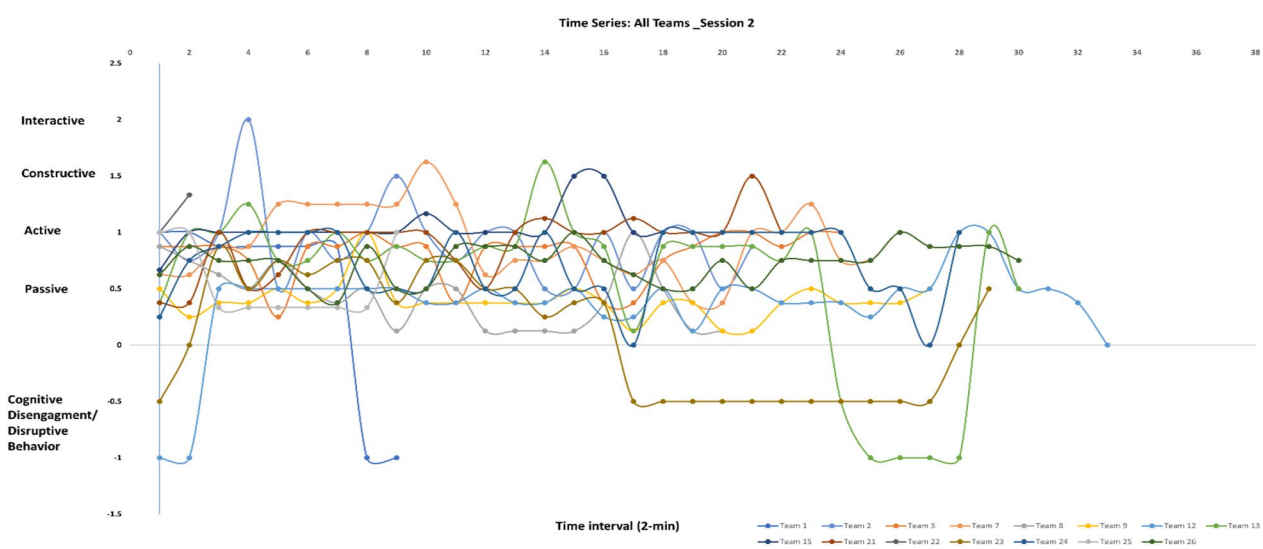

Fig. 3 Team members' collective levels of interactions during teamwork session two

In general, compared to the first meeting sessions, teams overall exhibited more disengagement behaviors and fewer constructive and interactive engagement behaviors during the second meeting sessions. However, overall, teams were active or passive most of the time, suggesting a positive level of engagement. The observed extended periods of disengagement occurred with only two teams and toward the end of the working session. For the most part, teams remained equally actively and passively engaged across both meeting sessions.

Characterizing changes over time

After analyzing the percentage change over time for all 12 teams and visualizing them in a bar graph (see Fig. 3), we identified three groups with similar patterns. The percentage change for each team is plotted and categorized into three groups based on the change. Group 1 includes teams 15, 21, and 22, denoted by the green bars in Fig. 4. Group 1 was characterized by being more engaged in session 2 than in session 1. Group 2 included teams 3, 12, 13, 24, and 26, denoted by the yellow bars in Fig. 4. Group 2 was characterized as being slightly less engaged in session 2 than in session 1. Group 3, composed of teams 1, 8, 9, and 23, denoted by the red bars in Fig. 4, consisted of less engaged teams in session 2 than in session 1.

When contrasting team interaction behavior from session 1 to session 2, a change was observed in teams' interpersonal relationships. Overall, students appeared to be more comfortable with each other in session 2 as compared to session 1. This characteristic was exhibited through in-call activities such as—increased personal communication like conversations about other classes, movies, shows, or just telling jokes. Changes were also observed regarding the use of physical space. For example, moving to a more relaxed workspace, couch, or bed, instead of their working desk. Also, students appeared less focused and more drowsy in session 2. Finally, students were also observed to be checking their phones, intermittently turning off cameras, and joining the meeting late more often in session 2 than in session 1.

Two different patterns of leadership roles were observed during the two sessions. In session 1, it was perceived that most of the teams had a leader or a facilitator (not necessarily the assigned scrum master, i.e., project manager) who led the session and the agenda items. There were also one or two relatively quiet or less engaged students in (almost) every team. Overall, the individual behaviors from session 1 appeared to be enhanced in session 2. More specifically, during session 2, most of the leaders retained their leadership roles while some of the facilitation was done by assigned scrum masters of session 2. Furthermore, the relatively quieter or less engaged students from session 1 became even quieter or less engaged.

Grouping and describing patterns of productive and unproductive team dynamics

Overall, team dynamics behaviors associated with teams characterizing group 1, teams that were slightly more engaged in session 2 than in session 1, were that team members within teams of this group demonstrated higher team leadership, communication, coordination, and monitoring from session 1 to session 2. Students of group 1 were overall more productive and showed fewer signs of being idle or disengaged in session 2 as compared to session 1. A general downward trend in feedback activities was also displayed from session 1 to session 2.

A representative case of group 1 is team 21. As shown in Fig. 5a, during session 1, all students in the team

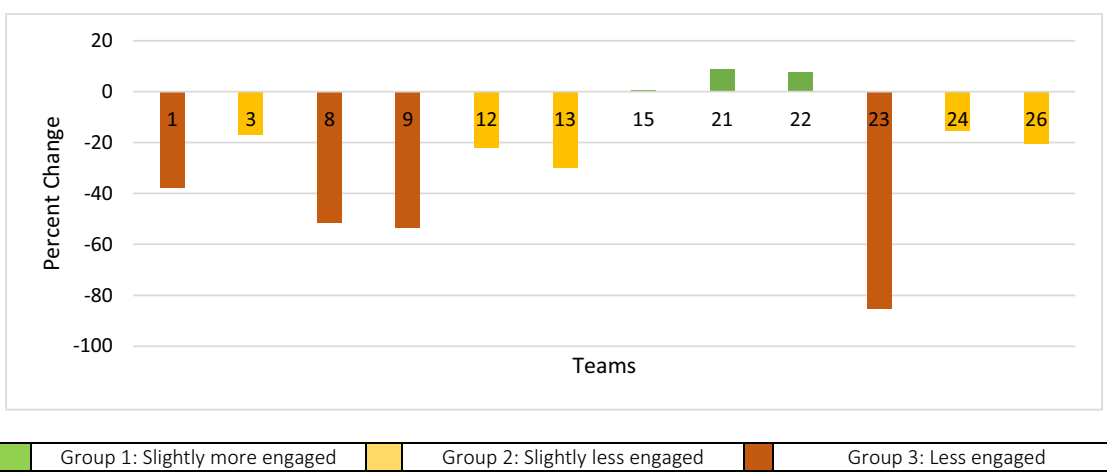

Fig. 4 Grouping of teams based on the percentage change in the level of engagement from session 1 to session 2

contributed mainly with teamwork orientation behaviors, equally with communication and feedback behaviors, and to a lesser extent with coordination behaviors. Then, as shown in Fig. 5b, during session 2, all students contributed with teamwork orientation behaviors, mainly student two and student three contributed to communication behaviors, and student one contributed to leadership behaviors.

Regarding team dynamics behaviors characterizing group 2, it was observed that teams in this group demonstrated about the same level of engagement in session 1 and session 2. However, the way the team members engaged represented a mix of trends. While the feedback and communication were reduced for many of the teams, team leadership and coordination increased. The types of engagement students demonstrated differed from session 1 to session 2, but overall, the frequency of engagement activities remained almost similar. Students of group 2 were overall similarly productive and showed similar signs of being idle or disengaged in session 2 as compared to session 1.

To showcase the team dynamics representing group 2, we describe team 3. As shown in Fig. 6a, during session 1, all students in team 3 contributed equally with communication, teamwork orientation, and feedback behaviors. Also, students one and two contributed to the coordination processes. Then, during team session 2, members of team 3 mainly focused on communication and teamwork orientation behaviors, as shown in Fig. 6b. To a lesser extent and mainly observed in student two, the team showed leadership, monitoring, and feedback behaviors.

Group 3 was characterized by team dynamics behaviors that overall demonstrated lower team leadership, communication, and feedback processes from session 1 to session 2. A sharp downward trend in coordination, tending almost to zero, was observed during session 2. Students of group 3 were significantly idler and less productive in session 2 as compared to session 1.

A representative case of group 3 is team 23. In session 1 and as shown in Fig. 7a, team 23 was overall focused on teamwork orientation with participation from all students. Also, during session 1, with participation from all students but to a lesser extent, all team members engaged in communication, feedback, and coordination processes. Then, during session 2, as shown in Fig. 7b, all team members engaged in teamwork orientation but slightly fewer times. They increased their communication processes, but not all team members participated. Student one initiated some leadership behavior, and between student one and student two, some monitoring and coordination behaviors were displayed.

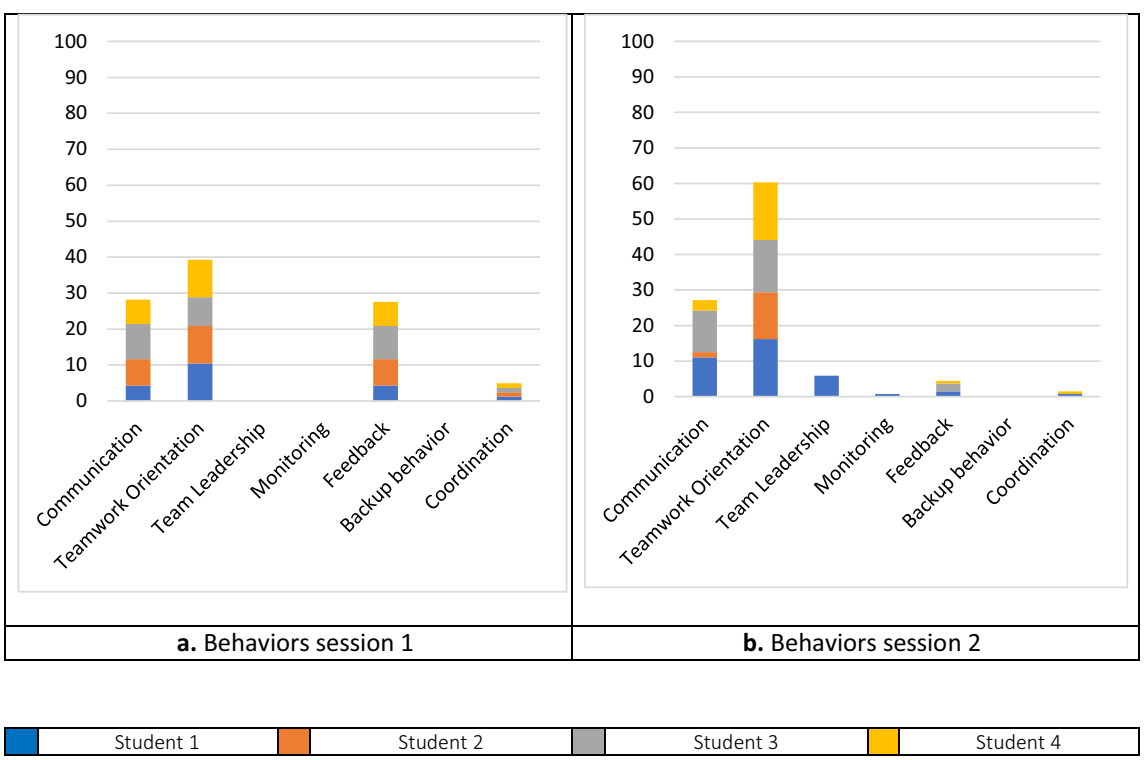

Fig. 5 Total counts and categorization of behaviors for team 21 during sessions 1 and 2

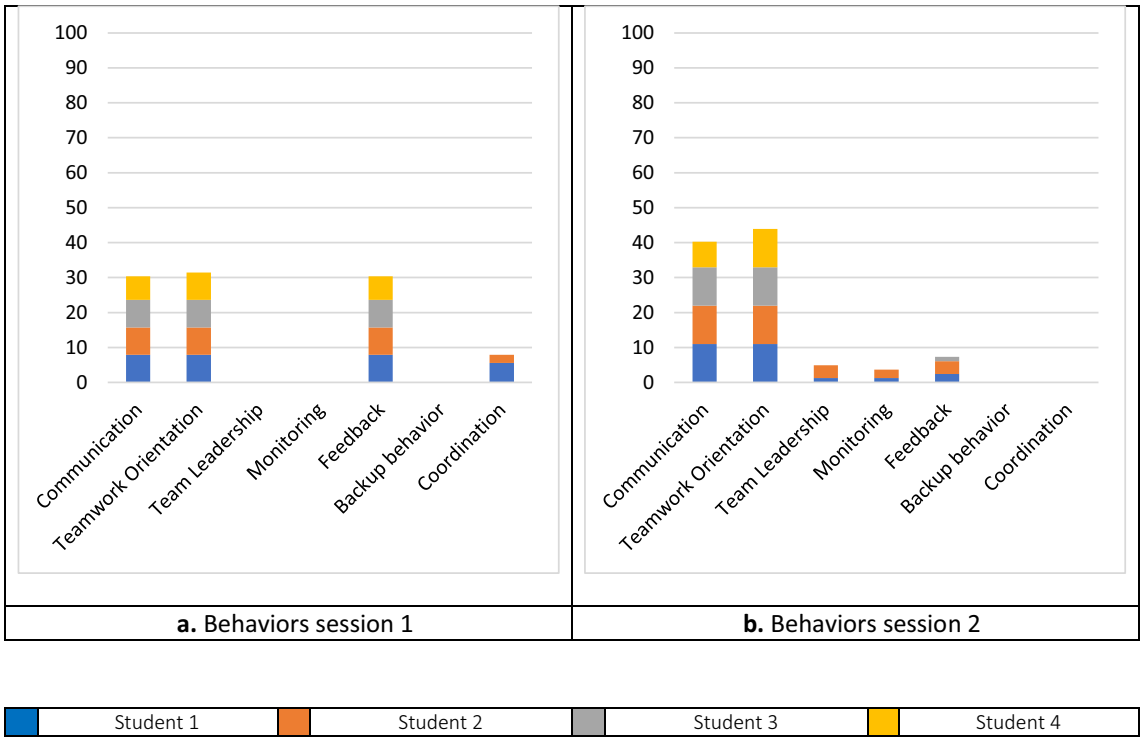

Fig. 6 Total counts and categorization of behaviors for team 3 during session 1 and session 2

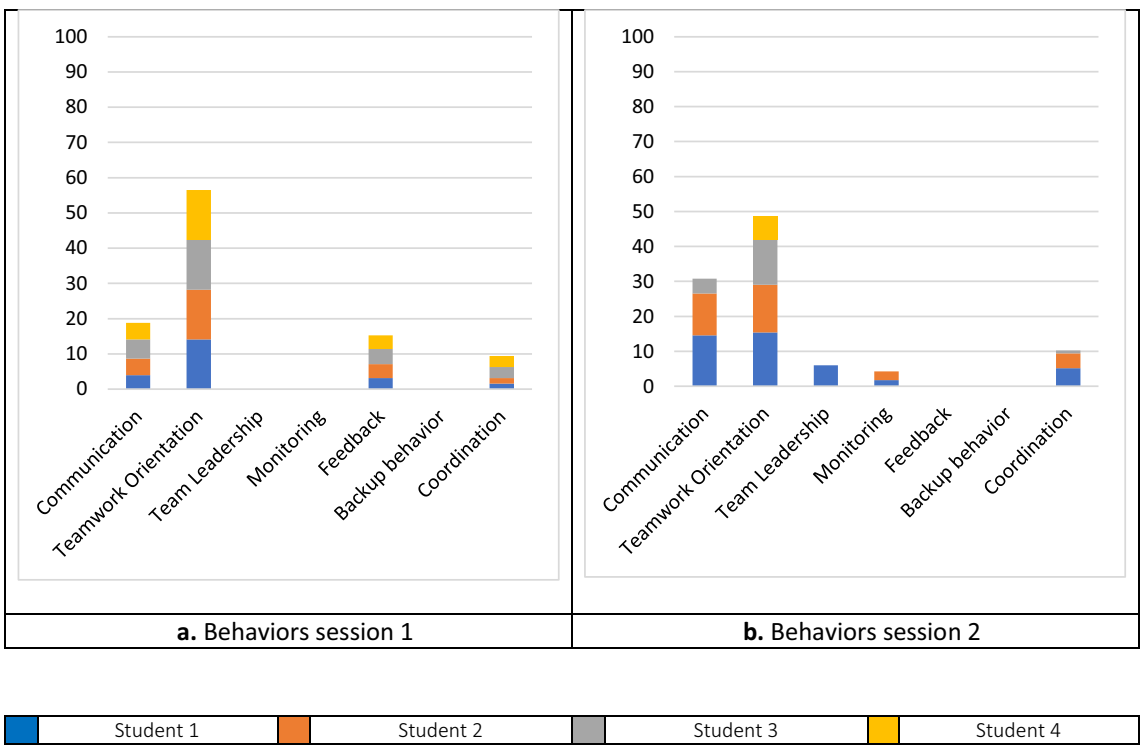

Fig. 7 Total counts and categorization of behaviors for team 23 during session 1 and session 2

Discussion and implications

Overall, the findings of this study characterize the different ways team members engaged in team dynamics processes during two working sessions at different points in the semester. This characterization involved (a) identifying specific teamwork behaviors such as communication, teamwork orientation, team leadership, monitoring, feedback, backup behavior, and coordination and (b) characterizing the degree to which those behaviors were exhibited by team members during a teamwork session. Findings indicate that most of the teams were active or passive, with very few instances of being constructive or interactive in both sessions. Being active indicated that the students were actually working or listening to other peers in the team give indications or explain a technique, as evidenced by being passive. Instances of disengagement or disruptiveness were not as common; thus, the students were actually working on the project but not necessarily working on the same task simultaneously. This finding could be attributed to the influence of the instructional intervention and course orchestration in two different ways. Firstly, Scrum prescribes having roles, dividing work to accomplish overall goals, and making each team member accountable (Bhavsar et al., 2020). This course structure may have promoted a "divide-and-conquer" approach to completing the project during teams' working sessions rather than working jointly to complete specific tasks. Secondly, by looking closer at potential differences between the first recorded teamwork session (week 4 of the semester) versus the second recorded teamwork session (week 10 of the semester), changes were observed regarding the types of interactions and the nature of work the team focused on during these sessions. In session 1, students focused on project planning and work assignments. The nature of these tasks could have potentially encouraged more collaboration from all team members since they needed to build alignment on the project plan and volunteer for individual tasks. By session 2, students may have been aware of their individual task assignments, so they might have worked more independently. This seemed to have led to overall less communication and longer periods of silence. It also appears that teams were more relaxed in their interaction approach in session 2. It was also observed that overall, students engaged in more independent work than collaborative work. This change in the level of engagement may be attributed to the specifications of the task students were working on. Specifically, students were supposed to work on milestone 3 of the project during session 2, which involved students working on their individual project contributions. Also, at times, especially when students turned off their cameras, it was impossible to detect if they were working on their individual tasks, listening to others, or disengaging. For instance, it was observed that students who were quieter from the beginning became quieter during the second team meeting. This behavior could have been influenced by the nature of the task, specific personality traits, or cultural orientations (Dinh & Salas, 2017).

Upon closer examination of the engagement levels in the first and second sessions, we identified three distinct groups: one group showed a slight increase in the level of interaction from session one to session two, another group exhibited a slight decrease, and a third group experienced a more significant decrease in the level of interaction. Despite the varying levels of engagement, one aspect remained consistent across these groups: their focus on communication and teamwork orientation. This involved students asking questions, engaging in casual conversations, assisting each other, and socializing. Further, in the second session, there was a decline in feedback-related behaviors, such as seeking and offering clarifications and asking for help. However, there was a noticeable emergence of monitoring behaviors, where team members started referencing each other's progress and tasks. The team behaviors exhibited in the second session suggest that teams may have evolved in their developmental stage. That is, behaviors exhibited in the second session can be associated with the norming developmental stage, where team members started to feel more comfortable with relationships, offered ideas and suggestions, and received feedback from their peers (Tuckman & Jensen, 1977).

Another notable observation was how leaders of teams emerged. As per scrum guidelines, students were asked to rotate the role of a scrum master (i.e., project manager) each session. However, some students took the role of scrum masters but did not assume facilitation roles during team meetings. Other team members did. This behavior could have resulted from students' inexperience in leading teams, making them unaware of what specific tasks they should have performed during the teamwork sessions. Although scrum masters were instructed to organize and submit the project milestones, they were not specifically asked to facilitate the group meetings as well. The implications of this finding suggest that team members may need training on performing as project leaders and engaging in facilitation and coordination strategies.

An important finding derived from meta-analytic research on teamwork is that contextual factors impact team effectiveness (Mathieu et al., 2019). Our study results align with this finding as it appears that many of the teamwork behaviors may have been the result of the influence of the instructional approach involving cooperative learning principles and the use of Scrum to manage

aspects of the project. Thus, the implications for teaching and learning involve providing students with behavioral expectations associated with different roles they must assume throughout the semester.

A second important implication of the study relates to the overall approach students followed to complete the project, either following a cooperative or a collaborative learning approach. Cooperative learning differs from collaborative learning in the sense that cooperative learning provides "a *structure* [emphasis added] of interaction designed to facilitate the accomplishment of a specific end product or goal through people working together in groups" (Panitz, 1999, p. 3), and collaboration is "a *philosophy* [emphasis added] of interaction and personal lifestyle where individuals are responsible for their actions, including learning and respect the abilities and contributions of their peers" (Panitz, 1999, p. 3). While our goal was to provide students with a situation where they would attempt to learn together, as aligned with cooperative learning (Dillenbourg, 1999), students in their teamwork experience focused on individual contributions to a common goal associated with collaborative learning, thus aligning with Scrum (Sutherland & Schwaber, 2011). However, a relevant observation concerned the instances when students were constructive or interactive. Such instances were characterized by the team members engaged in learning together by explaining concepts to each other or discussing each others' work. These instances can be described as truly cooperative, thus aligning with the essence of cooperative learning, such as students jointly discussing material with other students, helping other students, or sharing material among students (Smith, 1995). These two findings, in conjunction, are relevant because while the goal of cooperative learning is for team members to work and learn together, industry practices, particularly those associated with information technology fields, may promote collaboration, assuming that team members may have already developed a certain level of expertise to accomplish tasks individually, but jointly contributing to attaining project goals. This observation particularly applies to computing disciplines, where a collaborative approach may be preferred to a cooperative one, as it aligns better with project management industry standards, such as agile project management or Scrum (Masood & Farooq, 2017; Sutherland & Schwaber, 2011). However, this conjecture requires further studies to explore in detail how a collaborative or cooperative approach may result in greater individual learning and overall team performance. Findings for such investigations would enrich the teamwork literature, and researchers and practitioners can gather insights on how to improve team engagement and interactions. Insights could also be useful in developing interventions for improving how teamwork is taught in colleges, specifically in courses involving software development.

The practical implications of the study relate to providing teams with tools and structures that can help them coordinate their teamwork processes and promote interaction among team members. The combination of cooperative learning and scrum practices allowed them to implement collaborative and cooperative work as needed. Specifically, scrum practices allowed them to perform certain roles, construct specific artifacts, and engage in specific events that guided them through their processes for the project completion. On the other hand, cooperative learning provided them with an educational structure that opened in-class time to work and learn together and allowed them to be accountable. However, it was noted that additional training was needed when students took leadership roles in their teams. Thus, in future implementations of the course, we will provide students with further guidance and expectations of the role.

Regarding the theoretical implications, our study contributed to a better understanding of team dynamics during working sessions in the context of large-size software development courses that emerged as a result of teamwork pedagogy. Specifically, the findings described teams' levels of interaction, changes in the level of interaction over time, and the type of communication and coordination processes team members enacted when they interacted. These findings are significant because although work has focused on static characteristics of teams, such as team members' backgrounds and expertise, elements of team formation, or developmental stages, among other features, relatively little empirical work has examined the temporal aspects of teams, such as those occurring during working sessions occurring at different points in time (Delice et al., 2019).

Conclusion, limitations, and future work

Research on engineering and computing education has lacked consensus on effectively teaching teamwork skills. However, before answering this question, it is necessary to investigate the effects of pedagogical approaches. This study contributed to that end by closely investigating team dynamics that emerged as a result of implementing cooperative learning pedagogical principles combined with project management scrum practices. Our findings suggest that, overall, members of teams were mostly actively and passively engaged during meetings, were less constructive and interactive in their engagement, and mainly engaged in communication, team orientation, and feedback behaviors. Over time, team members' interactions with one another remained about the same, with feedback behaviors tending to diminish

and coordination behaviors staying about the same or slightly increasing over time. However, one of the limitations of our study relates to potential effects attributed to students' backgrounds, such as their culture or native language. Even though all students provided evidence of English proficiency, it may be the case that they may not feel comfortable speaking the language, thus explaining their lower interaction within their team. A second limitation relates to the potential effects introduced during team formation and how that may have impacted team trust. Thus, future studies must consider other students' characteristics, such as age or sex differences, sociocultural backgrounds, among others, as well as the effects of team formation. Despite the limitations, the study's findings provided important insights into students' interactions during teamwork sessions. Specifically, the findings suggest that students followed a collaborative approach instead of a cooperative one. However, although all teams successfully completed the project, future work is needed to investigate the relationship between the cooperative or collaborative approach and student individual learning and performance. The observations imply that more information is needed to make decisions and develop interventions that promote effective teamwork in colleges closely aligned with the workplace.

Appendix: implementation and deliverables for the semester-long project

Week	Deliverable	Description
Week 1	Milestone 0: Team formation	Teams of four members were formed, and they submitted a team contract together
Week 3	Milestone 1: Business case document describing the business needs and system requirements	Project vision statement, systems request, product roadmap, product backlog, context diagram, and team retrospective
Week 5	Sprint 1	Software prototype with two system requirements implemented
Week 6	Milestone 2: System proposal document describing the workplan, feasibility analysis, and requirements determination	Updated product backlog, use-case narratives detailing requirements of the system, project planning in a Gantt chart, project cost estimate in a cash flow, and team retrospective
Week 7	Sprint 2	Software prototype with four system requirements implemented
Week 8	Sprint 3	Software prototype with six system requirements implemented
Week 9	Milestone 3: System proposal document describing the functional, structural, and behavioral aspects of the system	Updated product backlog, functional model as activity diagrams, structural model as a class diagram, and behavioral model as a sequence diagram, updated project planning in a Gantt chart and team retrospective
Week 10	Sprint 4	Software prototype with eight system requirements implemented
Week 11	Sprint 5	Software prototype with ten system requirements implemented
Week 12	Milestone 4: System design specification document describing details of implementation	Updated product backlog, data storage mechanism as an entity-relationship diagram, hardware, and software deployment plan as a deployment diagram, revised Gantt chart, and cash flow
Week 13	Prototype usability report	Evidence of usability testing of the prototype and a discussion of design elements to improve the prototype for the final implementation
Week 14-Week 16	Final presentation	Final team presentation in the form of a sales pitch and a final prototype walkthrough

Author contributions

AM: conception and design of the work, interpretation of data, drafted and substantively revised the work; TA: analysis of data, interpretation of data, drafted the work; SA: analysis of data, interpretation of data, drafted the work; DP: acquisition of data, analysis of data.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to participants' privacy and confidentiality but are available from the corresponding author upon reasonable request.

Declarations

Ethics pproval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved as exempted by the University's Institutional Review Board from written consent

under Category 1 involving research conducted in established or commonly accepted educational settings involving normal educational practices.

Competing interests

There are no relevant financial or non-financial competing or conflicting interests to report.

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