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Acquisition of Teamwork Competence in a Hardware Course: Perceptions and Co-regulation of Computer Engineering Students*

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In work environments, it is essential for engineers to have a high level of teamwork competence. Therefore, engineering education programs aim to provide an environment where students can experience working in teams. In this study, perceptions and co-regulation of computer engineering students regarding teamwork were examined in a hardware course. A teamwork oriented approach based on individual and group reflections of students was designed and applied during an 8 week project study with the participation of 56 sophomore students of a public university in Turkey. In order to analyze different aspects of the teamwork acquisition process, convergent parallel mixed-methods design was utilized by using both quantitative and qualitative data. Quantitative data were collected by co-regulated learning questionnaire which was applied as pretest and posttest, and teamwork evaluation form that was used for self and peer assessment. Qualitative data were gathered by reflections and focus group interviews. The findings indicated that teamwork oriented approach had significantly increased co-regulation skills of students and they gained positive perceptions towards teamwork. Since most of the teamwork studies in computer engineering programs have been conducted in software engineering courses, applying a teamwork oriented approach in a hardware course provides a valuable contribution to the literature.

Keywords: teamwork assessment; co-regulation; students' perceptions; reflection; self and peer assessment; computer engineering education

1. Introduction

Nowadays, a high level of teamwork skills is one of the most required competencies in work environments for engineers [1–3]. However, students have the habit of studying individually and being competitive during high school due to the university entrance exams being centralized in many countries like Turkey. Since university is a transition period from high school to work environments, practicing teamwork activities as a student can contribute to their professional life after graduation. Therefore, it is important for students to experience working in teams especially during undergraduate education and enhance their teamwork skills [1, 4, 5]. As a result, undergraduate engineering education programs tend to integrate technical learning into team-based problem-solving experiences associated with the real world, in order to prepare engineering alumni to work collaboratively [6]. Having teamwork skills has positive effects on different aspects such as student confidence in performing higher-order tasks [7], self-confidence in problem solving [8], critical thinking [9], meta-cognitive awareness [10] and motivation [11, 12].

The abilities students should achieve in effective teamwork were studied and a list of these abilities was proposed by [1]. Thus, team members should be able to attend meetings, arrive meetings promptly, gather information and perform research when necessary, distinguish between the important and the trivial, express him/herself clearly, share opinions and listen to views of teammates, consider and adopt the suggestions of others when appropriate, provide and solicit help, show respect for other team members, introduce new ideas, be committed to team goals, accomplish a fair share of the work, complete individual tasks promptly and with high quality [1]. Team members are expected to discuss objectives and standards for tasks, behave strategically during monitoring, review processes and outcomes, use appropriate technological tools, and cope efficiently with the challenges they face [13]. Therefore, successful cooperation in a team can be accomplished through conscious self-regulation and co-regulation between team members [14].

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Each team member should take responsibility for regulating his/her learning (self-regulated learning) and support other group members in regulating their learning (co-regulated learning) [15, 16]. Since team members bring their own ideas, conceptions and self-regulatory abilities to teamwork [17], self-regulation in a collaborative context is a bi-directional process [18]. Therefore, co-regulation can be described as the interaction that coordinates the self-regulation processes between two or more peers [14]. The goal of co-regulation is to guide, support and influence regulation of the learning processes of peers through interpersonal interactions [17].

For an effective teamwork process, a suitable environment for the development of co-regulation of learners should be provided. Co-regulation activities involve goal setting, monitoring, and reflection that are performed collaboratively with the interaction of team members [19]. Reflections can be individual or group reflections that provide an opportunity for team members to consider their personal contributions and act collaboratively as a team [20]. In this regard, individual and group reflections of students were used in this study for formative assessment of the development of teamwork skills.

Effectiveness of teamwork can be measured with self and peer assessment of team members [1]. Students can grade their own work and their peers' work as part of self and peer assessment. Due to the engineering classes being crowded [21] and the administrative burden of applying self and peer assessment outweighing the perceived benefit [2], self and peer assessment in higher education had been relatively less-used in engineering contexts. However, with the introduction of self-peer assessment tools such as WebPA [22] that reduce the workload, self and peer assessment are getting used more commonly in recent years. In order to analyze teamwork attributes every team member has developed based on the views of themselves and their teammates, self and peer assessment were utilized in this study.

Due to the educational potential of teamwork, numerous studies have been conducted for teamwork skills acquisition during undergraduate education in engineering disciplines such as electrical engineering [2], biotechnology [3], civil engineering [4] and computer engineering [1, 23, 24]. Most of the teamwork studies in the computer engineering field were conducted in software courses, especially the software engineering course [23, 24]. Since software engineering course is generally taught in the 3rd or 4th year of the curriculum, providing students the opportunity to experience teamwork in an earlier course can be more beneficial [5]. Also, hardware courses in the curriculum cover both theoretical and practical studies, and students generally work in pairs in the lab hours and projects. Therefore, hardware courses are convenient to conduct teamwork studies by nature. However, a gap in the literature that concerns team based approaches in hardware courses has been observed. In this regard, performing a teamwork oriented approach in a hardware course can provide a valuable contribution to the literature. Therefore, we decided to focus on Logic Design course and follow a student centered approach to investigate how students develop teamwork skills. Logic design is taken as one of the first hardware courses in the second year of computer engineering education that provides the foundation for other hardware courses like embedded systems, and microcontrollers. Teamwork competencies students acquire in logic design course can also be useful in the following courses of the curriculum. Another reason for selection of this course is the fact that students perceive this course as difficult because they experience problems such as loss of motivation and reduced level of success due to the crowded classrooms [21, 25].

The aim of this study is to guide and monitor computer engineering students to facilitate the acquisition of teamwork competence in a hardware course. Therefore, a teamwork oriented approach based on individual and group reflections and supported by self and peer assessment is designed to examine the co-regulation and perceptions of students.

2. Methodology

This study is conducted by using convergent parallel mixed-methods design. This approach contains a set of procedures to concurrently collect both quantitative and qualitative data, analyze them separately, compare and/or synthesize the results, and make an overall interpretation of the results to confirm and/or complement each other [26].

The quantitative phase of the study includes data collected by a co-regulation scale, and self and peer assessments. The effect of the followed teamwork oriented approach on the co-regulation of students was investigated by applying one group pretest-posttest research design. In the qualitative phase, focus group interviews and individual reflections were conducted in order to gain an understanding of how participants experienced the teamwork process.

In order to support the students to acquire teamwork competence, the following research questions have been sought in this study:

1. Does the followed teamwork oriented methodology have a significant effect on students' co-regulation skills?

2. What are the perceptions of students regarding teamwork in Logic Design course?

Research question 1 is involved with the quantitative phase of the research design, while research question 2 is related to the qualitative phase.

2.1 Study Group

The study was conducted at a public university in Turkey during 2018–2019 academic year with 56 sophomore students of the department of computer engineering taking Logic Design course for the first time. Students were assigned a team based project. The number of team members was determined as 4 based on suggestions in previous studies [9, 12]. Students were not allowed to choose their teammates themselves, because it is suggested for students to be assigned in random groups and work with the classmates they are not familiar with [4]. Therefore, teams were formed randomly in a heterogeneous manner according to gender and academic success [12]. 14 project teams were formed with each team consisting of 1 female and 3 male students (One team had 2 female and 2 male members). 26.79% (N = 15) of the students were female while 73.21% (N = 41) of them were male. Cumulative grade point average (CGPA) scores of students were taken into consideration to randomly assign students to groups and to form teams with heterogeneous members who have low and high CGPAs. Average CGPAs of the teams is 2.46 while the minimum is 1.94 and the maximum is 2.79.

2.2 Research Process

The research was conducted as part of Logic Design course which consists of 3 theoretical hours and 2 practical hours. The course covers the following topics: number systems, introduction to logic circuits, combinational logic circuits and sequential logic circuits. The teamwork oriented approach is applied as a project that combines the theoretical information and practical experiments. All teams were assigned the same project that involves the first three topics of the course and includes the design and implementation of a solution to a real world problem. In order to provide a flexible and collaborative environment that the students can develop teamwork skills, the project was designed to have four independent modules and another module combining them. By assigning a multi-phase project, each student was able to work interactively in a collaborative environment, where team members can share their independently developed ideas with the rest of the team [27], take into account other views and adapt to different roles and responsibilities [11].

Table 1 presents the timeline of the teamwork oriented methodology, which includes the activities, data collection instruments, and group reflection tasks, in a weekly manner (data collection instruments will be presented in the next subsection). At the first week of the study, a meeting was held to inform students about the teamwork oriented approach, to introduce the project and to announce the teams. A handout that contains the guidelines that must be followed during the teamwork process and the documents that have to be delivered was prepared and shared at week 1. Also, Co-regulated Learning Questionnaire was applied as pre-test in this week.

Teams performed project activities during weeks 1–6. In a similar way with the team progress reports utilized in [13], teams were asked to deliver weekly group reflections (GRs). Two project meetings were organized with the participation of all teams and the instructor at week 3 and 5. These meetings facilitated the monitoring of the team development progress and provided feedback to the teams [11].

Table 1. Timeline of the teamwork oriented methodology

Week	Activities	Data Collection Instruments and Group Reflection Tasks
1	Project meeting for introduction of the project and teamwork oriented approach	Pre-test: Co-regulated Learning Questionnaire
2	Teamwork activities on projects	Group Reflection 1
3	Teamwork activities on projects, Project meeting and lecturer feedback	Group Reflection 2
4	Teamwork activities on projects	Group Reflection 3
5	Teamwork activities on projects, Project meeting and lecturer feedback	Group Reflection 4
6	Teamwork activities on projects	Group Reflection 5
7	Presentations of the projects, and delivery of project reports	Individual Reflections Teamwork Evaluation Form
8	Feedback	Post-test: Co-regulated Learning Questionnaire Focus Group Interviews

In addition to the course hours, a meeting room (between weeks 2–7) and extra lab hours (during weeks 4-7) were provided to teams. In extra lab hours, teams were able to perform project activities for 2 hours and get feedback from the lab assistant. The research process is specifically designed to provide as much feedback as possible to facilitate the cooperation and decision making of the teams [28].

Instead of using project grades as summative assessment, the research was based on the observation of the teamwork competence acquisition process by focusing on formative assessment. In this regard, group reflection (GR) form, individual reflection (IR) form, and teamwork evaluation form were used as formative assessment tools. Group reflection forms were used by the instructor to monitor the progress of the teams weekly with the aim of developing students' co-regulation and planning skills as a team. Five GR forms were prepared and students were asked to fill these forms online as a team on a weekly basis. Google Open Documents was used to gather these GRs as it provides a collaborative working environment to create, edit, share, and collaborate on documents [15]. In group reflection forms, it was expected from each team to report: (1) their plans for the related week, (2) how much of their plans they were able to execute with the participation of which team members, (3) the activities they planned for the following week. These questions are about project planning and the collected data were not analyzed as qualitative data; however, they were evaluated weekly by the instructor to provide feedback to the teams.

At week 7, teams presented their projects and delivered project reports that include design, simulation, and implementation of their circuits. Students also provided individual reflections and teamwork evaluation forms [1] individually. Finally, post-test and focus group interviews were conducted at week 8.

2.3 Data Collection and Analysis

Data collection process and data analysis were conducted as quantitative and qualitative (Fig. 1). Quantitative data were collected by Co-regulated Learning Questionnaire and Teamwork Evaluation Form. The effect of the followed teamwork oriented approach on the co-regulation of students was investigated by applying Co-regulated Learning Questionnaire developed by [14] and adapted to Turkish by [29] as pretest and posttest. Cronbach alpha internal consistency scores of the scale were calculated as 0.80 [14] and 0.89 [29], respectively. Cronbach alpha scores exceeded 0.7 in both studies, which indicates good internal reliability [30]. When applied as pre-test, the students were asked to answer the questionnaire according to their previous experiences and perceptions towards teamwork. In the post-test, they were expected to answer the questions based on their experiences in this study.

Co-regulated Learning Questionnaire includes 19 items that use a 4 point Likert rating scale with the options "Never"(1), "Some of the time"(2), "Most of the time"(3), "Always"(4). This questionnaire includes questions about project management, collaborative working skills, time management, motivation and co-regulation of team members. Example items of this questionnaire are "In our group we looked over each other's work to see if we understood what each member was doing", "At the end of each day, we left enough time to plan for the next day", "We double-checked each other's work to make sure we were all doing it right". While analyzing the results of the pretest and posttest, if the difference between the mean scores is significant, the effect size is calculated with Cohen's metric for the paired samples t-test [31]. It is stated that Cohen's d value can be interpreted as 0.20 (weak effect) 0.50, (moderate effect) and 0.80 (large effect) [31].

Teamwork evaluation form developed by [1] was used for self and peer assessment. This form includes 18 questions that must be answered by each team member to evaluate themselves and other team members. These questions correspond to the list of abilities each student should achieve in an effective team [1]. Since students work with their peers continually during the course of the project and depend on their contributions, teamwork evaluation form is a valuable source to observe team dynamics.

In the qualitative phase of the study, individual

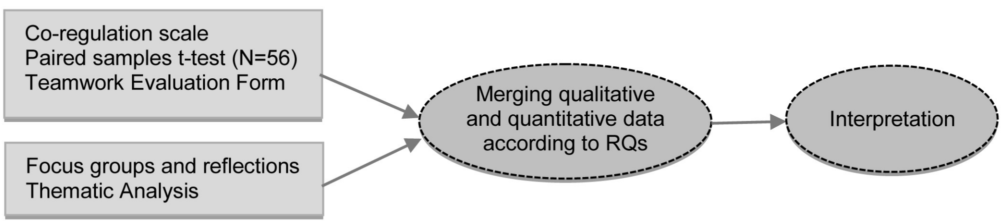

Fig. 1. Data collection and analysis.

Table 2. Pre- and post-test results of co-regulation skills

	Pre-test		Post-test			Cohen's *d*-value
	M	SD	M	SD	t-test	
Co-regulation skills	60.77	7.04	63.04	7.14	2.611	0.349

reflection form and semi-structured focus group interview form were used for data collection. Qualitative data gathered by these two sources were analyzed using thematic analysis with Nvivo 12. Thematic analysis is used to identify, analyze and report patterns (themes) within data [32]. During the thematic analysis, six steps suggested by [32] were followed: (a) transcribing, reading and re-reading the data, (b) generating initial codes, (c) searching for themes, (d) reviewing themes, (e) defining and reviewing themes, (f) producing the report. In the analysis of qualitative data, the coding process was conducted by the third author. After the thematic scheme emerged, 10% of the data was coded by the first and second authors. As a result, it was seen that the data set was coded in the same way, and the consensus among the coders was found to be 100%.

The individual reflection form was prepared to be applied at the end of the teamwork process to get individual feedback. Individual reflections include the following prompts about students' reflections on team performance as a group and their individual contributions: (1) which aspects of the teamwork process can you describe as positive? (2) which aspects of the teamwork process can you describe as negative? (3) in which aspects can the teamwork process be enhanced? (4) which tasks did you undertake in the teamwork process? (5) what did you gain as a result of the teamwork process? 56 students filled individual reflection forms and 5577 words were reached after the analysis.

Feedback regarding experiences and suggestions of students about the teamwork oriented approach were gathered by focus group interviews (FGI). FGI form includes questions about the experiences and perceptions of team members related to the research process. FGIs were conducted with 16 voluntary students organized as two sessions of 8 students each. In total 9 male and 7 female students attended the interviews. FGIs were recorded with the permissions of the students, took 57 min 18 sec in total and 4194 words were reached after transcription of the recordings.

3. Results and Discussion

3.1 Quantitative Results

Mean scores of pretest and posttest obtained from co-regulated learning questionnaire were analyzed by paired samples t-test and descriptive statistics regarding the results are presented in Table 2. Mean scores of posttest were higher than mean scores of pretest. Paired samples t-test results indicated that the difference between posttest and pretest scores was statistically significant [$t(56) = 2.611$, $p < 0.05$]. Thus, it can be expressed that the teamwork process had significantly increased co-regulation skills of students. However, Cohen's d value (Cohen's $d = 0.349 > 0.20$) states that the effect size is weak [31]. This may be the result of the limited timeline of the project, as students require more time to internalize teamwork competence [1, 27].

Moreover, quantitative data obtained from Teamwork Evaluation Forms were analyzed based on self and peer assessment (Table 3). Self-assessment results indicated that the five items that scored the highest were item 16 (100%), item 4 (98.21%), item 1 (94.64%) and item 5 & 9 (92.86%). The items at the top of the list suggest that students were good at communication and time management skills. The lowest rated items were item 3 (71.43%), item 17 (78.57%), item 15 & 18 (82.14%) and item 6, 12 & 13 (83.93%). The items at the bottom suggest that students have relatively weak self-confidence about the tasks they performed.

On the other hand, peer-assessment results showed that the highest rated items were item 13 & 16 (92.68%), item 2 (90.24%), item 1 (89.63%) and item 5 & 9 (89.02%). Two of the top six items of the peer-assessment results were different from self-assessment results. These items indicate that students have the perception that their peers generally completed their individual assignments with acceptable quality and arrived nearly all meetings on time. These findings show that students were relatively more satisfied with the quality of the work performed by their peers. This may be the result of their perception regarding relatively weak self-confidence obtained from self-assessment or students may have filled the forms in a modest way for their peers as it is suggested that students are often reluctant to negatively criticize other students [1]. The five items that scored the lowest were item 3 (70.12%), item 11 (77.4%), item 7 (78.04%), item 10 (79.54%) and item 8 (81.09%). Four of the five items were different from the results of the self-assessment. These items were related to requesting and receiving help and considering and adapting sugges-

Table 3. Results of teamwork evaluation form

	Teamwork Attributes	**Self**	**Peer**
No	**Did the team member . . .**	%	%
S1	Attend nearly all team meetings?	94.64	89.63
S2	Arrive on time for nearly all team meetings?	89.29	90.24
S3	Ever introduce a new idea?	71.43	70.12
S4	Ever openly express opinions?	98.21	88.41
S5	Communicate clearly with other team members?	92.86	89.02
S6	Share knowledge with others?	83.93	86.58
S7	Ever consider a suggestion from someone else?	89.29	78.04
S8	Ever adopt a suggestion from someone else?	85.71	81.09
S9	Generally tried to understand what other team members were saying?	92.86	89.02
S10	Ever helped someone on the team?	89.29	79.54
S11	Ask for help from someone on the team?	87.5	77.4
S12	Generally complete individual assignments on time?	83.93	81.7
S13	Generally complete individual assignments with acceptable quality?	83.93	92.68
S14	Do a fair share of the work?	89.29	82.92
S15	Seem committed to team goals?	82.14	84.75
S16	Generally show respect to other team members?	100	92.68
S17	Demonstrate an ability to do research and gather information?	78.57	83.53
S18	Show an ability to distinguish between the important and the trivial?	82.14	82.92

tions from other team members. This finding can be explained with the students having the perception that their peers were relatively less helpful to each other and less open to suggestions of their teammates. Item 4, which indicates that students openly expressed their opinions, obtained the second highest ratio in self-assessment. This shows that students have the perception that they expressed their opinions; however, their peers were not open to suggestions.

The highest ratio obtained from both self and peer assessment was item 16 with 100% and 92.68%, respectively. For self-assessment, every student stated that they generally showed respect to other team members. However, as part of the peer assessment, this item shares the top spot with item 13 with a relatively lower ratio (92.68%). This can be interpreted as each member claiming to be respectful to other members while not receiving the same respect from them. The lowest ratio obtained from both self and peer assessment was item 3 with 71.43% and 70.12%, respectively. Students had the perception that all team members including themselves were relatively weak at introducing new ideas. This can be due to the fact that the project requires the students to synthesize related course topics and use course materials and the Internet as resources. Thus, the students may have the perception of not introducing new ideas.

3.2 Qualitative Results

Qualitative data were collected by individual reflections and focus group interviews. Individual reflections of every team member were gathered at the end of the teamwork process [12, 15] with open ended questions [12] about team performance as a group and their individual contributions. Individual reflections were collectively analyzed with focus group interviews. Results of the thematic analysis were classified under three themes: (a) benefits received, (b) problems experienced, (c) suggestions. Thematic framework about these themes and sub-themes is presented in Fig. 2a.

3.2.1 Benefits received from the teamwork oriented approach

Benefits of the followed approach were categorized under six themes according to the coding frequency as "Reinforcement of course topics", "Social/Communication skills", "Time management", "Collaborative problem solving", "Taking responsibility", and "Teamwork awareness" (Fig. 2b). These sub-themes are explained below with quotations.

Reinforcement of course topics: It was mentioned by students that working on a project as part of a team was very useful to comprehend course topics. This finding correlates with [12], as team interactions

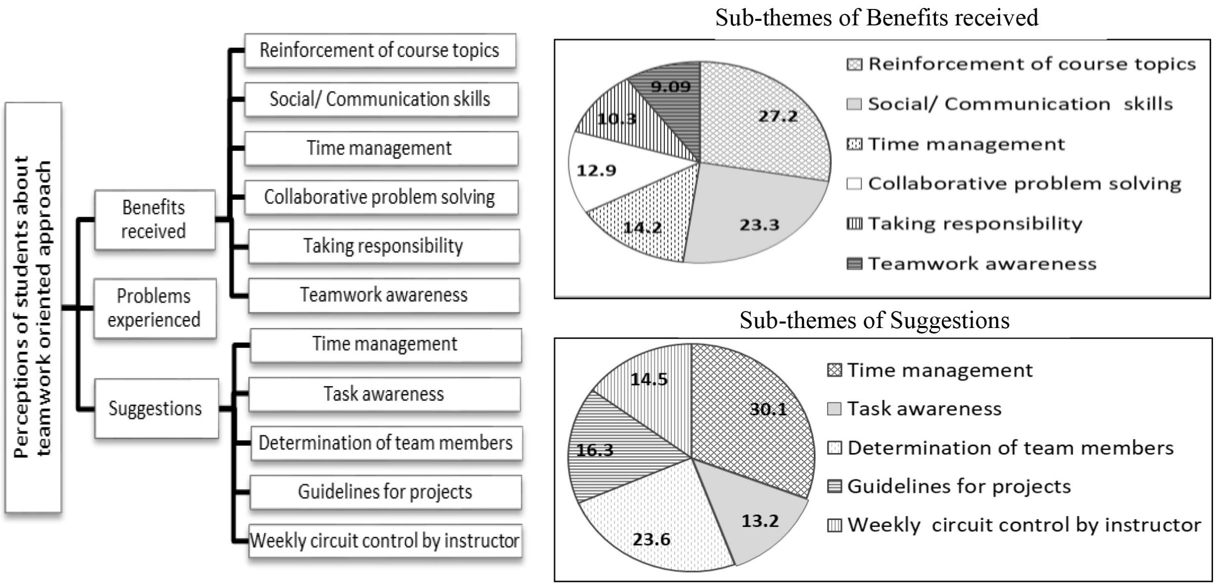

Fig. 2. (a) Thematic framework (b) Percentages of "benefits received" and "suggestions" themes.

assist students to benefit from deeper learning. This sub-theme has the highest coding percentage (27.2%) under "Benefits received" theme. Some quotations regarding this benefit are given below.

> *"In my opinion having a project as a part of the course was beneficial. Because the more you practice, the better you comprehend the course. I didn't need to study for the midterm of the course."* (FGI-1)
>
> *"With this project, I comprehended many topics that I didn't understand while implementing circuits in lab hours."* (IR)
>
> *"Instead of performing only theoretical work, the project helped me to practice by implementing circuits and reinforce what I learned."* (FGI-2)

Moreover, one of the students mentioned that she learned from her teammates by expressing her view as:

> *". . . We shared tasks in our team and every member developed his/her part of the circuit. Then we shared our knowledge. This way, every member implemented only one module of the project but learned about the whole project."* (FGI-2)

Social / Communication skills: Students indicated that teamwork had positive effects on their social/ communication skills. This finding is also parallel with the finding of [23], which was conducted in a software engineering course, where 85% of students indicated that teamwork helped to improve their communication capability to other members. Since engineering students are more introverted and less inclined to communicate with others than the general population of students [27], the development of this skill is especially meaningful for the contribution of this study. Under "Benefits received" theme, this sub-theme is involved with 23.3% of the coding. Some quotations mentioned by the students about this benefit are expressed below:

> *"I think I've improved my communication skills. My classmates, who I was not familiar with, became close friends after spending a lot of time on the project as team members."* (IR)
>
> *"I had never had a dialog with my team members before the project. I learned how to study as a team, to listen to and discuss different opinions and to develop a project with people I didn't have close relations with."* (IR)
>
> *"I learned how to work more compatible with people I haven't known before."* (FGI-1)

Time management: Students expressed that the teamwork oriented approach contributed to their time management skills. Time management sub-theme constituted 14.2% of the coding in this theme. The gains students have achieved are stated as follows:

> *"Without teamwork, usually there is no time management and every task is done at the last moment. However, in teamwork, every team member tried to perform his/her own task. So a project plan was formed and every member tried to follow it. If it was an individual project, I would not have worked so planned."* (FGI-2)
>
> *"With the help of the teamwork, I realized the importance of using time more efficiently to meet deadlines."* (IR)

Some of the students mentioned that weekly group reflections also had positive effects on their planning and time management skills. For example, one of them expressed this as follows:

> *"In order to write the group reflections, we worked on determining the tasks that we need to do. Otherwise, we wouldn't have started working on the project and finished it on time."* (FGI-1)

Collaborative problem solving: It was mentioned by students that, with the help of teamwork, they gained benefits about solving problems by dividing the project to smaller tasks and delivering a final product after integrating them. The perceptions of students regarding collaborative problem solving are parallel with the findings of [4]. In collaborative studies, self-regulation is a bi-directional process in which team members seek feedback from and provide feedback to their teammates [16, 18]. In this regard, time management and planning are also important for effective collaboration [11]. 12.9% of the coding in "Benefits received" theme was related to this sub-theme. Some experiences regarding this benefit are given below.

> *"The project contributed us to find practical and reasonable solutions when we face problems."* (IR)
>
> *"It helped me to get experience of co-operation and to overcome problems as a team."* (IR)
>
> *"In case of unexpected situations, teamwork was very useful to be ready to solve these problems as a team."* (IR)
>
> *"I think that teamwork made us realize that we can solve problems faster by dividing them into smaller tasks."* (IR)

Taking responsibility: This sub-theme composed 10.3% of "Benefits received" theme. Students stated that teamwork contributed to the development of their sense of responsibility. For example, a student expressed his view as:

> *"Working as a team helped me to be more responsible and develop my awareness."* (IR)

Another student stated that because of her responsibilities to her teammates, she worked harder for the course and added:

> *"When you work as a team, you are responsible to your teammates. So we feel that we need to be more focused on the course."* (FGI-2)

Teamwork awareness: Some of the students mentioned that they gained awareness about teamwork. This sub-theme constitutes 9.09% of the coding in this theme. The students expressed their opinions on this subject as follows:

> *"I realized that it is easier to work on different tasks concurrently as a team."* (IR)
>
> *"I experienced that teamwork is useful to learn from your teammates and to share your knowledge with them."* (IR)

3.2.2 Problems experienced

In individual reflection form and FGIs, students were asked about the problems they experienced during teamwork activities. 39 of 56 students (69.64%) participated in IRs stated that they did not encounter any problems. This can be interpreted as the overall teamwork oriented approach being successful. On the other hand, students who experienced problems stated that some of their teammates did not participate in group meetings, caused delays while performing the assigned tasks or failed to fulfill their duties on time:

> *"The fact that my teammates did not fulfill their responsibilities on time made me feel that they did not care about the course and the project. Even though everyone has a duty, there has been little or no exchange of information at group meetings. If I haven't reminded the deadlines, my teammates wouldn't be able to complete their tasks on time."* (IR)
>
> *"Although everyone has completed their duties at the end of the study, those who haven't done their tasks on time or have performed them after my warnings disturbed me."* (IR)

These statements can be explained with some students not understanding the teamwork process, or not committing to the roles and responsibilities of team members [1].

3.2.3 Suggestions

Students made suggestions for the improvement of the teamwork oriented approach to their teammates and instructor under two sub-themes (time management, task awareness) and three sub-themes (determination of team members, guidelines for projects, weekly circuit control by instructor), respectively (Fig. 2b). 30.1% of the coding included in the suggestions theme was about time management. Some of the suggestions were declared as follows:

> *"We could have made a better project if we were more organized and scheduled team meetings better."* (IR)
>
> *". . . As a team, we've presented a good project, but we should learn how to use time more effectively."* (IR)
>
> *"Although we had used the time well, we could have finished the project earlier with better planning."* (IR)

They also stated that task awareness of students should be high for efficient teamwork. Task awareness constitutes 13.2% of the coding. A student expressed his view as:

> *"The task awareness of everyone should be improved, team members must be aware of their responsibilities without the warning of another member."* (IR)

These two sub-themes, which were for their teammates, were directly related to the second theme that is about problems students experienced during the teamwork process. In this regard, time management and task awareness of team members should be high for an efficient teamwork process, which is in line with [13] that suggest performing task analysis for better group performance.

As part of the three sub-themes of the suggestions for the instructor, students shared ideas about the determination of team members. This sub-theme constituted 23.6% of the coding in the suggestions theme. Even though students stated that working on a project with classmates they were not familiar with helped them improve their social and communication skills, some of them mentioned that their teamwork activities could have been more effective if they were able to work with the members they choose.

> *"If we were able to choose our teammates, students with the same goal and strong communication skills would work together. I think this will result in more efficient teamwork."* (IR)

Since most of the students declared that they haven't experienced any problems, this finding may be expressed by the students who had problems working with their peers. Thus, getting feedback on weekly reflections about possible conflicts in teams can be considered for future work [23].

Some of the students stated that they needed more explicit guidelines for the project. This sub-theme constituted 16.3% of the suggestions. Students mentioned their suggestions as follows:

> *"Specifications of the project could have been given clearer or we could have been more flexible in our circuit designs."* (IR)
>
> *"There was very little information about the project. We had to ask questions every week but we couldn't get precise answers. This caused the project to progress slowly."* (IR)
>
> *"It could have been very useful to be given more detailed information about the project specifications and its evaluation."* (IR)

Some students suggested that the instructor should check whether the tasks written in group reflection forms were carried out on the circuit on a weekly basis. "Weekly circuit control by instructor" forms 14.5% of this theme. Some quotations are given below:

> *"If there were weekly controls by the instructor to check our circuit implementations, we would have to comply with the planning reported at the group reflections."* (FGI-2)
>
> *"If the instructor checked whether designs stated in weekly group reflection forms were implemented on the circuit, the reflections could have been much more realistic and our circuit designs would be parallel with the reflections."* (FGI-1)

Since students have a tendency to work independently and are not experienced in teamwork, they might have needed more strict guidelines and control mechanisms [11]. It should be noted that the teamwork oriented approach was specifically designed in a flexible manner to let the students be more creative with their designs, take more responsibility, plan and solve problems collaboratively, and improve their co-regulation skills. However, these suggestions related to guidelines and control mechanisms were acceptable, because all of the students may not change their perceptions towards teamwork in a short period.

Results of the teamwork evaluation form correlate with the findings of qualitative data analysis. The highest rated items of both self and peer assessment were directly related to social/communication skills and time management sub-themes. Moreover, some of these items were associated with teamwork awareness and taking responsibility subthemes. On the other hand, the lowest rated items of self and peer assessment results were different. Items with the lowest ratios in self-assessment were distributed to different sub-themes as collaborative problem solving, social/communication skills, time management, and task awareness. However, four of the five lowest rated items in peer assessment were directly related to the collaborative problem solving sub-theme. Therefore, it can be interpreted that students had the perception that their peers were relatively weak at collaborative problem solving compared to them.

Overall, the findings of this study are parallel with the findings of previous teamwork studies [1, 4, 11–13, 23, 24, 27]. Moreover, the findings obtained at a hardware course in this study are in line with the findings of studies conducted at software engineering courses [23, 24]. It is stated by [23] that more research is required in both conflict management and team confidence in future teaching of the software engineering course. This suggestion also matches with our findings in the hardware context, as conflicts among team members were discussed as a potential reason for some of the sub-themes in problems and suggestions themes. Also, team confidence issues were observed as part of the least developed teamwork skills on peer assessment results.

4. Conclusion

Integrating teamwork into various courses and teaching students how to work collaboratively as a team should be an integral part of engineering and computer science education. In this study, perceptions and co-regulation of computer engineering students regarding teamwork were examined in a hardware course. In order to guide students to acquire teamwork skills and develop co-regulation competence, a teamwork oriented approach was followed based on supporting and monitoring students to plan and find solutions to problems collaboratively. Mixed-methods design, which is based on using both quantitative and qualitative data, was utilized in this study to examine different aspects of the teamwork acquisition process. The findings of quantitative data analysis indicated that co-regulation skills of students were increased in a statistically significant way with the teamwork oriented approach. Moreover, the results of qualitative data analysis supported these findings and pointed out that students gained positive perceptions towards teamwork.

Considering the fact that most of the studies about teamwork were conducted in software engineering courses, applying a teamwork oriented approach in a hardware course provides a valuable contribution to the literature. Our findings at a hardware course were parallel with the software engineering context; however, getting similar feedbacks at an earlier course of the curriculum would help both the students and the instructors in the remaining courses of the curriculum as students would be more experienced with teamwork.

Since changing student behavior in positive ways with respect to teamwork effectiveness takes time and requires practice, it shouldn't be expected from all students to acquire teamwork competence fully in a short time. The more teamwork is integrated into engineering education, the more students will be able to internalize teamwork competence. In this regard, the duration of the followed approach can be seen as the main limitation of this study. Since the study group consists of 56 students taking one course, the relatively small sample size can cause the findings to have limited generalizability and can be interpreted as another limitation of the study. However, the findings of the study were positive; therefore, this study can be interpreted as a step in the right direction. In this regard, studies aiming to develop students' perceptions in the long term can be the subject of future research.

Students expressed that the followed approach helped them to reinforce course topics. Since the focus of the study was the acquisition of teamwork competence and the effect of the project and the teamwork approach were intertwined, it cannot be analyzed whether the reason of this feedback was conducting a project or following the teamwork oriented approach on their projects. Therefore, another future work direction can be to examine the effects of individual projects and team projects on comprehending acquisitions of the course.

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