Chapter

Developing Collaborative Skills through STEM Approach

Chairil Faif Pasani and Rizky Amelia

Abstract

Collaborative learning is a practice that dates back centuries. In Confucius' classic text, Li Ji, there is a famous saying that one becomes narrow-minded when learning without friends. Therefore, collaborative skills not only allow students to interact with others but also enhance their opportunity to learn, which differs significantly from individual learning. Collaborative problem-solving is crucial in science, technology, engineering, and math (STEM), which are fraught with complex challenges like climate change, overpopulation, welfare, resource management, health, and biodiversity. The Systematic Literature Review (SLR) approach was used to find, assess, evaluate, and interpret all of the research that was accessible in order to create this book chapter. Preparing the youths with a collaborative mindset is crucial for addressing the issues and difficulties that arise in real life. This review specifically focuses on developing technology-based collaborative skills through STEM approach to reflect the trend of integrating technology into education.

Keywords: collaborating skills, STEM approach, technology, education, Systematic Literature Review

1. Introduction

The abilities in question are theoretically grounded on the principles of social constructivism, wherein learning takes place through social interactions [1]. This section adopts Dillenbourg's broad definition of collaborative skills, which refers to a situation where two or more people learn or attempt to learn something together [2]. There is also an increasing demand for new collaborative forms due to the widespread application of modern digital tools and social networking platforms [3, 4]. Common scenarios today in both in-school and out-of-school environments may include (a) a community of gamers discussing mechanisms to solve emerging technical bugs; (b) a small team working in an online chat room to solve a math problem; and (c) a class using discussion boards asynchronously to brainstorm ideas on a science topic [5]. Meanwhile, in practice, the key to defining specific forms of collaborative skills is to determine their various pragmatic parameters:

1. The scale of collaborative skills can range from as small as a couple to a large community. The timing can vary, such as in a year-long course or a one-time activity (for example, a team-building activity in a company).

2. The setting can change from physical collaborative skills to virtual learning.

3. The medium can include various technology platforms and others [6].

Besides these pragmatic parameters, the dynamics of collaborative skills are influenced by various forces, such as the preference for individualism or collectivism in relation to learning objectives. When learning goals are established for individuals, collaborative skills prioritize improving individual knowledge or skills. In the Programme for International Student Assessment (PISA) test, the Organization for Economic Co-operation and Development (OECD) defines students' collaborative problem-solving competence as the capacity of individuals to effectively engage in a process, where two or more agents attempt to solve a problem [7]. This entails the collaborative sharing of knowledge, skills, and efforts in order to collectively work toward the attainment of a solution.

In summary, when education is focused on communal objectives, the emphasis is placed on fostering community cohesion and collaborative knowledge development. The pedagogical approach known as 'team-based learning' centers on fostering small group dynamics within a classroom environment, wherein tasks are designed to facilitate both individual learning and team growth [8]. Similarly, advocates of 'communities of practice' [9] or knowledge building [10] emphasize the importance of building communities among students. Communities of practice are groups of people who share a common concern or passion for what they do, and regularly interact to learn how to do it better [9]. Knowledge building emphasizes collective knowledge creation and innovation as well as prioritizes the advancement of community knowledge over individual achievement [11].

Another force that influences collaborative skills is the division of work. In many learning scenarios, the teacher organizes the work division, where tasks are divided into independent sub-tasks, and the group assembles the different parts together [12]. Collaborative learning is often utilized in these cases. On the other hand, in other collaborative skills opportunities, work is not divided but rather negotiated and completed by the individuals involved [13].

All group members contribute to the same learning task in a collaborative learning environment. In contrast, inside a competitive academic setting, pupils tend to operate autonomously and exert efforts to surpass their peers. Nevertheless, it is important to note that collaboration and competitiveness are not inherently contradictory concepts. Contradictions can play a pivotal role in propelling the development of an activity system [14]. Similarly, competition can be a positive element for collaborative skills [15]. This often occurs alongside collaboration within or across group learning settings [16]. A competitive mindset can be a double-edged sword and can facilitate collaborative problem-solving processes when carefully crafted and well-utilized.

Many curricula, instructional guidelines, and instructional materials connected to STEM have emerged in recent years. Even though the majority of the early attempts at STEM education focused on one or more of the STEM topics alone, proponents for stressing links between or among the subjects in STEM education are growing [17]. Due to the earlier lack of integration, STEM-related research frequently has a wide variety of foci and contexts. While other more thorough studies may address additional and deeper relationships among the STEM disciplines, the study contexts of some STEM-related studies may only involve one of the STEM fields [18]. The potential benefits of using educational technology to enhance STEM learning outcomes are being emphasized by educators and academics more and more as a result of the rapid growth of information and communication technology [5, 19]. This study provides compelling evidence that collaborative skills effectively address critical issues in STEM education.

The Systematic Literature Review (SLR) approach was used to find, assess, evaluate, and interpret all of the research that was accessible in order to create this book chapter. With this approach, the author conducts systematic journal reviews and identifications, going through each stage in a set order. Researchers gathered journal articles from Google Scholar, Research Gate, SINTA, DOAJ, and Scopus to finish this manuscript. STEM education and collaborative education are key terms.

2. Benefits of collaborative skills in STEM education

Collaborative skills have been well-embraced in STEM education [20, 21]. It is advisable to establish student learning communities as a means to enhance student engagement and perseverance in STEM programs inside educational institutions [22]. Multiple meta-analysis studies have demonstrated that the acquisition of collaborative abilities has a positive impact on overall student learning [4, 23]. Moreover, a more recent meta-analysis revealed that collaborative skills supported by computer technology have demonstrated notable effectiveness in STEM education, specifically in process, knowledge, and affective outcomes [24].

The study presents substantial evidence that collaborative skills are an effective means of addressing crucial challenges in STEM education [25]. An issue that can be identified is the phenomenon of low enrolment coupled with great interest [22, 26–28]. The cultivation of collaborative skills possesses the capacity to enhance students' self-esteem and sense of accomplishment through the facilitation of their assistance to others and engagement in the co-creation of classroom activities. Students can develop HOTS (Higher Other Thinking Skills) and learn better in STEM content through collaborative skills than individual learning [29]. In addition, collaborative skills can foster students' communication skills to resolve conflicts [30].

Another issue is equity in STEM education. Female students generally have lower enrollment rates but higher dropout rates in STEM majors compared to male students. Similarly, students from low-income families show similar patterns compared to high-income families [26, 27]. Previous studies have shown that students' satisfaction with the positive experience of collaborative skills makes them more intrinsically interested in learning. This has consequently made them more willing to attend school and persist in STEM learning. In addition, the cultivation of collaborative abilities facilitates effective communication and interdependence among individuals within a group, irrespective of their racial, gender, or academic backgrounds. This, in turn, contributes to the establishment of a learning environment that is characterized by fairness and equality [31, 32].

3. Collaborative skills and technology in STEM education

The utilization of technology is of paramount importance in enabling the development and enhancement of collaborative abilities. The utilization of visual representations in educational contexts can facilitate the comprehension and completion of learning activities, facilitate collaborative processes, and function as a supportive framework for the construction of shared knowledge [33]. This study centers its attention on instances of technology that provide direct support for collaboration within the learning process. While several technologies have the potential to support collaborative abilities, their impact is not considered important. This assertion is substantiated by the findings of Lee et al. (2016) in their report, wherein students engaged in the collection of their activity data, such as step counts over a specific duration, through the utilization of sports watches. Subsequently, these students acquired statistical knowledge by collaboratively examining and analyzing the collected data within group settings [34]. The sport watches were solely used for data collection, and not to facilitate collaboration. This type of study is beyond the scope of this chapter.

4. Developing collaborative skills through STEM approach

4.1 The environment of remote collaborative skills

Audio and video conferencing platforms, such as Zoom and Skype, are extensively utilized in contemporary synchronous remote learning environments. The aforementioned tools facilitate the connection of students in different locations [35]. They frequently incorporate distinct functionalities that enhance collaboration abilities, such as screen sharing, chat rooms, and annotations. Babaian and Schiano presented a set of practical recommendations aimed at enhancing the effectiveness of small-group collaboration within the context of online learning [36]. The aforementioned skills encompass the ability to facilitate teachers and students in becoming acquainted with functionalities that facilitate small-group collaboration. This entails effectively managing display names and altering screen names to reflect group identification or names, seamlessly transitioning between group workspaces and the primary space, communicating messages to all groups or specific groups within breakout spaces, and possessing a comprehensive understanding of sharing and annotation tools.

Furthermore, research has been performed to investigate these characteristics. Singhal (year) demonstrated the utilization of breakout rooms within the Zoom platform for the purpose of conducting a virtual pharmacotherapy course throughout the COVID-19 pandemic [37]. In class, every five to six students were grouped and placed in a breakout room, hence the teacher could move around the room to facilitate discussions. The study emphasized that the use of breakout rooms can assist students' small team tasks in promoting active learning, consequently leading to more participation.

4.2 Multi-user virtual environments (MUVEs)

MUVEs have been used to facilitate collaborative skills. In these environments, students typically use avatars to interact with each other in a virtual world, similar to multiplayer online role-playing games [38]. Additionally, these environments have the potential to provide educational advantages for students diagnosed with autism spectrum diseases [39]. River City is an exemplary instance in the field of science education, as it serves as a pioneering model for a Multi-User Virtual Environment (MUVEs) learning platform. This innovative educational tool has been specifically developed to effectively involve students in middle grades in the application of scientific inquiry techniques that align with established criteria (https://muve.gse.harvard.edu/) [40].

The curriculum was enhanced through several development versions [41]. For example, the first unit focuses on biology and ecology. Students can connect through avatars, and investigate an authentic problem (e.g., disease outbreak in a city) in a virtual city with a river running through the environment. In order to solve a problem, students can collaborate by sharing information and communicating with team members about the collected data through a chat text tool. In retrospect, [42] concluded that MUVEs have been identified as effective instruments for facilitating student-centered collaborative inquiry learning, offering a viable alternative to traditional inquiry-based science instruction methods.

In this study, Ibanez et al. introduced a novel 3D virtual collaboration skills model designed to facilitate and direct students' collaborative activities within Multi-User Virtual Environments (MUVEs) [43]. The model establishes synchronization learning points to achieve individual or group desired learning goals, as well as work division to promote positive interdependence. Based on the model, students conducted a case study in which participants (through avatars) navigated a 3D environment and collected information related to available theater performances in order to purchase tickets for the shows they wanted to attend. They also performed several collaborative activities, such as information sharing and group assessment. The factors affecting interactive collaboration were identified in the first iteration and the design was refined. This resulted in improved collaboration in the second iteration [43].

Unlike the examples mentioned earlier that gave a game-like setting, [42] described a geometry unit for fifth graders, wherein students engaged in various activities within a virtual classroom. In this environment, they were able to manipulate virtual 3D geometric objects, observe their classmates' problem-solving processes, as well as provide feedback and critique to each other. According to their findings, the experimental group outperformed the control group in terms of geometry learning. Moreover, the most effective way for students to acquire abstract geometry ideas is to collaborate with their classmates and practice manipulating virtual objects (e.g., by viewing and critiquing each other's answers) [44].

It is noteworthy that manipulating virtual items can enhance peer-to-peer interactions in real life. Jackson et al. designed a math game activity on a table to augment and reinforce what students had learned in their fourth-grade math class [27]. The students were expected to use components from their resource pool to fill in the blanks on a math problem displayed in the center of the table screen (allowing multiple users to edit the content simultaneously). Four students work together in a group, with each possessing resources that could potentially contain important components of the problem-solving solution. They were required to collaborate in order to complete the task. The students responded positively to the collaborative game-based learning exercise. Upon completing the program, male students' arithmetic scores showed substantial improvement.

In conclusion, MUVEs and audio/video conferencing systems are examples of mechanisms that connect students online. Although these technologies are now widely used in everyday life, there is still a need for further empirical studies to determine the exact elements of these tools that can most effectively enable collaborative learning [45]. Meanwhile, MUVEs not only provide alternative and shared areas for students to learn, but they also simulate various work environments [46]. Students are likely to feel more engaged in the problem-solving process when they can experience it authentically by exploring virtual environments and interacting with virtual objects.

4.3 Facilitate written discourse in groups

Tools for audio or video conferencing that make remote communication more convenient and effective, require high-speed Internet connection and gadgets equipped with cameras and microphones. In contrast, written discourse can fulfill the needs of collaborative skills without such constraints.

a. Synchronized discussion forum

In synchronous discussion forums, students can participate in real-time using written text or symbols [47, 48]. This type of forum is also known as online chat. Some advanced forms of this forum, designed for educational purposes, incorporate simulated intelligent agents that can offer students real-time feedback on the discussed topics and facilitate communication between participants. According to Wang, Rosé, and Chang, high school students collaborated in pairs in several geology-related brainstorming activities [49]. They used a synchronous chat program called VIBRANT, which included an integrated virtual agent capable of providing real-time comments.

Using a similar platform called MentorChat and virtual agents, Tegos et al. demonstrated collaborative learning among 96 university students on human-computer interaction [50]. In both educational settings, virtual agents were seen as additional participants in the team dialog, offering remarks and posing leading questions derived from their discourse content. Both studies demonstrated the beneficial impact of virtual agents on enhancing students' collaboration abilities.

b. Asynchronous discussion forum

An asynchronous discussion forum allows students sufficient time to analyze the posts made by their peers and provide more useful comments to the forum. This tool provides the benefit of meeting students' requests for rapid interaction and feedback. In a study examining the efficacy of collaborative learning in an undergraduate engineering course, participants were instructed to engage in group discussions pertaining to assigned teamwork and afterward submit a collective report derived from their email-based communication [51].

The web, shared by multiple users, such as blogs, can serve as an asynchronous discussion forum to exchange viewpoints. For example, [42] used an educational blog to engage 21 high school students in examining the issue of acid rain. A learning community was established for each student on the blog, where they shared their results and commented on their colleagues' findings. According to the results, students showed increased interest in the activity [52].

Through their activities on the blog, the students have shown social and emotional support for each other, leading to increased construction of new information. An investigation into how students collaborate was conducted with a total participation of 25 pre-service teachers who used an asynchronous online whiteboard to communicate with each other [53]. The students were divided into groups of five and tasked with developing an interdisciplinary education module that included elements of math and science. Each member in the group can upload their design ideas, while others can comment, make suggestions for modifications, and rate them. Despite the absence of an initial allocation of tasks by the teacher, the students assumed distinct responsibilities and assumed leadership positions (such as soliciting feedback, contributing knowledge, and exerting control over the topic), which were evenly distributed among team members. This occurred even though there was no initial work division by the teacher.

Discussion forums, both synchronous and asynchronous, have been around for quite some time. However, they are constantly evolving with the emergence of new technologies. In recent years, multimodal inputs like audio or video were incorporated into online discourse platforms, such as the Flipgrid app. Moreover, machine-based learning algorithms have been embedded to support automated and customized student feedback [48].

4.4 Provide direction for the collaborative processes

The previously mentioned technologies generate more opportunities for students to work together by connecting across different locations and times. Nonetheless, the collaboration may not always be successful due to various reasons, such as inefficient communication, lack of interaction, and inappropriate work division [54]. Affordable collaborative scripts in computer-based learning environments have been investigated as a means to guide collaborative activities. Rummel, Mulins, and Spada used a total of 106 middle school students to investigate scripted collaborative arithmetic learning. They modified a computer-based teaching program called Cognitive Tutor Algebra to include scripts that allowed users to work together [55].

After initially working on separate challenges individually, two students eventually teamed up at a computer to address a challenge presented by a script, integrating their respective problems. During the collaboration, additional scripts emerged to encourage collaborative behavior at specific times (e.g., contributing based on independent problem-solving experience, listening to peers, and asking questions for clarification). The results showed students who followed the scripts demonstrated better collaborative skills and were more successful in finding solutions to problems compared to other groups that did not follow the scripts.

Collaborative scripts have been employed for many objectives, encompassing the facilitation of collaborative conduct and serving as a mechanism for peer surveillance. The study conducted by Bouyias and Demetriadis aimed to examine and contrast the impacts of compulsory peer monitoring prompts and fading scaffolding scripts in a collaborative argumentation task inside a computer science educational setting. The students participated in an online argumentation learning environment called iArgue [56]. Random pairs were formed between 34 students who belonged to two different classes. In the peer-monitoring group, when student A submitted a task, peer B would receive the submission along with a peer-monitoring prompt asking them to check whether A's argumentation followed the model. In case it does not, student B was expected to indicate where improvements are needed. The monitoring task should be completed before student B can continue their work. Besides the peer-monitoring prompts, consistent scaffolding scripts were also provided (e.g., guidance on argument construction).

Students in the fading group did not receive any prompts for peer monitoring, instead, they were provided with a fading scaffolding script. This means there was less scaffolding after the students' second post. According to the results, the scripts that encourage peer monitoring significantly improved learning outcomes. In another study that investigated the function of collaborative scripts in argumentative learning, these scripts not only served as peer monitoring prompts but also guided students to systematically analyze their partner's argumentation and encouraged their argumentative construction. These activities include guiding students to paraphrase, criticize, ask questions, provide counterarguments, and propose new arguments. Another benefit of using collaborative scripts in argumentative learning is that they encourage students to develop their argumentative constructions [57].

A total of sixty students participated in the study, each of whom worked with a partner on a task that required knowledge from both of their respective fields of study. Specifically, the partnership consisted of two students, one with a background in water management and the other with a background in international development studies. The texts were successful in facilitating the development of argumentation knowledge [58].

The findings indicate that collaborative scripts have the potential to successfully facilitate and improve collaborative processes through the promotion of collaborative behavior, peer monitoring, and knowledge production. This is particularly evident in small-group collaborations. This is true for collaborative scripts used in online environments. Consequently, there should be greater emphasis on incorporating collaborative scripts into educational practice, and more studies on methods that enable collaboration among larger groups.

4.5 Produce, store, and visualize collective knowledge

Besides expanding opportunities for collaborative work and providing direction for collaborative processes, technological tools and platforms have also been developed to facilitate the generation and sharing of collective knowledge by the groups. An example of this is Wikipedia, an online encyclopedia that has grown over the past 20 years and currently has over 56 million entries available in more than 300 different language editions (https://en.wikipedia.org/wiki/List of Wikipedias). It has rapidly developed into one of the most popular websites. A concept behind Wikipedia states that anyone can contribute to the world's most comprehensive encyclopedia. This reflects the latest popular advances in humanity's pool of knowledge.

Several examples of Wikipedia and similar technologies are used in educational settings at various levels. Pifarre and Kleine Staarman investigated the collaborative processes that occur when elementary school students work together on a science book in the context of a wiki. The study focused on student-generated writing from a dialogic perspective, considering the number of paragraphs, words, sentences, and reasoning relationships [59]. This analysis was conducted on student-generated texts, and the conclusion suggests that dialogic methods should be used to examine the process of collaborative interaction. This approach can help create more effective pedagogies related to wiki use in educational settings. Furthermore, a student-centered inquiry learning paradigm has been created and implemented for use in college biology classes as part of the WIKIed Biology project, supported by the National Science Foundation [60].

The students participated by collaboration through the use of Web2.0 technologies, managing and tagging educational resources obtained from the Internet. They collaborated in small groups to create and publish website pages based on their scientific inquiry projects. The results showed that the students significantly improved their understanding of various biological concepts, as well as their ability to think critically and their awareness of the relevance of scientific communication.

Similar to Wikipedia's crowdsourcing model, "citizen science" can be seen as the practice of delegating various scientific endeavors to the general public. The term "citizen science" is used to describe the practice of nonprofessional scientists (such as data collection) by contributing to the generation of professional and scientific knowledge [61]. Digital Earth is an initiative that involves individuals in the collection and conversion of information related to the Earth into digital form [62]. OpenStreetMap (www.openstreetmap.org), an example of Digital Earth, is a collaborative effort to produce a free and editable map of the world populated with geographic data provided by individual users. YouthMapper, a student branch of

OpenStreetMap, which can be accessed online at www.youthmappers.org, is a global network of students who are actively engaged in collaborative mapping projects using OpenStreetMap. Gama et al. [42] examined the collaborative mapping experiences of students from three different institutions in Europe, North America, and Africa. The study found that participating in Mapathons events ("mapping marathons") not only improved students' technical ability and subject knowledge but also enhanced their engagement as socially responsible citizens [42].

Knowledge forums, led by Marlene Scardamalia and Carl Bereiter over three decades of study and development, are a pioneering platform for communal knowledge construction in upper-middle-class spaces [63]. These forums serve as tools to assist and support groups in developing their knowledge. Students compile their knowledge records in relation to specific subjects. One of the strengths of the forum is the provision of multiple scaffolds that students can use to develop their submissions. For instance, students can start a statement by selecting a pre-defined question, such as "My Theory" or "My Understanding Problem," and can also add comments on top to offer a high-level overview. Empirical studies on the topic have shown that students have found the benefits of Knowledge forums in developing their fundamental, domain-specific, and epistemic literacies [64].

The iKOS platform is a web-based knowledge organization tool that enables cross-disciplinary collaborative learning in a classroom environment [65]. The platform allows students to generate, exchange, and organize information. It also has the benefit of incorporating multimodal features [66, 67]. In Wiki mode, students can create knowledge entries similar to those on Wikipedia, while they can tag and annotate images or photos in PicTag mode. In mind mapping mode, they can create concept maps to visualize the relationships between big ideas. In Flipbook mode, they can publish their multimodal pages and interactive flipbook to the general public. This activity supports multiple modes of knowledge representation. According to the results, after completing a lesson on nuclear power, prospective science teachers were able to create a rather voluminous knowledge network [68].

Personal response systems (such as clickers), and polling applications are other technology categories that attract attention. An instructional technique known as Peer Instruction is established to engage students in typically lecture-based classroom conversations. These resources are often effective with Peer Instruction instructional practices. When using clickers or polling software, it is necessary to project and view the distribution of student responses on the screen. This allows students to be motivated to talk to their neighbors about their decisions and thought processes, as the projection of the class' collective state of knowledge engages them in conversation. This strategy has been proven effective in improving student learning and retention through STEM approach [69].

The platforms mentioned above provide a space for students to store, create, and exchange collective knowledge with each other. In addition to improving the community and building knowledge by contributing to the collective knowledge, the students can also benefit from developing their individual knowledge and other personal skills in the process.

5. Evaluation of technology-based collaborative skills through STEM approach

Despite its widespread use, there is a relatively limited amount of empirical study conducted in evaluating technology-based collaborative skills. The assessment of collaborative learning gained can be viewed from two different perspectives, namely collaborative outcomes and processes. Collaborative outcomes refer to what the group produces during the learning process. This collective output can be analyzed to infer the collaborative processes or individual understanding of teamwork. Meanwhile, the processes examine the complex dynamics (such as social interactions among group members), which serve as a link between the individual and the group.

In order to develop products, the discourse documented has been utilized in various technology platforms during the collaborative learning process. For example, synchronous or asynchronous discussion forums can record the discourse that occurs between members of a learning community. This provides a rich data source for evaluating and analyzing the collaboration and knowledge construction among members.

Jimoyiannis and Angelaina investigated Community of Inquiry (CoI) and Social Network Analysis (SNA), using a total of 131 blog posts that addressed the issue of acid rain [52]. Through the use of CoI analysis, community characteristics were examined by classifying publications into three categories, namely social presence (i.e., not involving domain knowledge but for emotional communication and group cohesion), cognitive presence (i.e., involving domain knowledge), and teacher presence. Teacher presence was defined as the presence of a teacher in a publication (i.e., including instruction or scaffolding). The SNA analysis provided a quantitative representation of the engagement level of individuals as well as their social relationships. The amount of direct contact each member has with others may indicate the power distribution among students.

The use of external technologies, such as video or audio recordings, to analyze collaborative processes is frequent. This approach can be used to investigate the collaborative processes. Talentino investigated the use of a mixed reality environment to enhance the study of earth science by high school students. The discourse between students and teachers (e.g., questions and answers) as well as among students, were analyzed and coded using video and audio recordings (e.g., comments, questions, or responses between individual students). The statistics revealed a visible increase in the number of statements driven by student participation. This activity is a usual practice for computer-based learning platforms to track students' activities as they use the platform (e.g., time stamps, clicking on buttons or pages, editing text) [70].

Several previous studies have focused on analyzing log data to gain a deeper understanding of collaborative processes within groups. Altebarmakian and Alterman [68] investigated how elementary school students solve arithmetic problems using an online platform with an intelligent virtual tutor under three different learning conditions, namely collaborative, individual, and combined. They also evaluated the effectiveness of each student's problem-solving approach within the context of their learning conditions by analyzing log data of students' interactions with the virtual tutor. This analysis included students' attempts, errors, and hint requests [71].

Some studies focus on both collaborative procedures and their products. For example, [68] investigated the extent to which 29 university students engaged in collaborative work during a computer science and psychology class by analyzing the data recorded through the system and the substance of the posts made by the students. The students worked on their assignments in groups of three to five using an educational blog as their platform of collaboration. They were required to independently draft and upload their answers to the initial problem, comment on posts made by others, respond to questions posed by others, modify their solutions in light of the group conversation, and eventually submit final responses [68].

The participation of each student in the group project is assessed with respect to their cognitive, social, and behavioral habits during the activity. The measurement of their reading, editing, and commenting behaviors, as tracked by the system, provides insights into their behavioral engagement. The log data also revealed that students' interaction levels depended on whether they referred to previous statements made by their peers. Subsequently, the level of cognitive engagement was evaluated based on the topics covered in the students' contributions.

An important observation regarding the assessment component of the study on collaborative learning is that most studies use assessments to test the effects on individual students' academic or emotional outcomes. However, these tests do not necessarily reflect the development of students' understanding of collaboration or their ability to work together effectively. Therefore, it is crucial they receive timely and useful feedback on their individual and group efforts when participating in learning activities that require collaboration. Continuous assessment of collaborative learning facilitates meaningful communication, not only among collaborative group members but also between students and teachers. Therefore, students have a more positive experience when participating in collaborative learning.

6. Conclusion

The limitations, strengths, and advantages of collaborative learning through STEM approach are outlined in this chapter. The chapter additionally presents instances of technologies that enhance collaboration skills through many means, including facilitating communication among students across different temporal and spatial contexts, fostering written and multimodal exchanges among students, providing guidance for collaborative procedures, and supporting the development of collective knowledge. Further exploration is needed for formative assessment of students' collaborative knowledge and practices. In addition, the assessment of students' collaborative skills should be explored, with a focus on evaluating the effect of collaborative learning on students' academic and affective outcomes (individual) as well as conducting formative assessment of collaborative knowledge and practice.

Author details

Chairil Faif Pasani* and Rizky Amelia
Universitas Lambung Mangkurat, Indonesia

*Address all correspondence to: chfaifp@ulm.ac.id

References

[1] Vygotsky L. Interaction between learning and development. Readings on the Development of Children. 1978;**23**(3):34-41

[2] Dillenbourg P. Collaborative learning: Cognitive and computational approaches. Advances in learning and instruction series. New York, NY: Elsevier Science, Inc.; 1999

[3] Hesse F, Care E, Buder J, Sassenberg K, Griffin P. A framework for teachable collaborative problem solving skills, assess. In: Teach. 21st Century Ski. Methods Approach. Dordrecht: Springer; 2015. pp. 37-56

[4] Chen J, Wang M, Kirschner PA, Tsai C-C. The role of collaboration, computer use, learning environments, and supporting strategies in CSCL: A meta-analysis. Review of Educational Research. 2018;**88**(6):799-843

[5] Kelley TR, Knowles JG, Holland JD, Han J. Increasing high school teachers self-efficacy for integrated STEM instruction through a collaborative community of practice. International Journal of STEM Education. 2020;**7**:1-13

[6] Lai ER. Collaboration: A Literature Review. Vol. 11. Pearson Publ; 2011. p. 2016

[7] Eijkelhof H, Dillon J, Redfors A. Curriculum policy implications of the PISA scientific literacy framework. In: Electronic Proceedings of the ESERA 2013 Conference, Strand 10, Science Curriculum and Educational Policy. ESERA; 2014. pp. 26-33

[8] Michaelsen LK, Sweet M, Parmelee DX. Team-Based Learning: Small Group Learning's Next Big Step. New Directions for Teaching and Learning. Number 116. Vol. 103. United States: John Wiley & Sons; 2008

[9] Wenger E, Trayner B, De Laat M. Promoting and assessing value creation in communities and networks: A conceptual framework. Rapport. Netherlands: The Dutch Ministry of Education, Culture and Science; 2011

[10] Chan T-W et al. One-to-one technology-enhanced learning: An opportunity for global research collaboration. Research and Practice in Technology Enhanced Learning. 2006;**1**(01):3-29

[11] Scardamalia M, Bereiter C. Knowledge Building. Canada: The Cambridge; 2006

[12] Nugraha F, Siahaan P, Chandra DT. The effect of structured individual responsibility on students' achievement increase in cooperative learning science class. Journal of Physics: Conference Series. 2019;**1157**(3):32066

[13] Micari M, Pazos P. Beyond grades: Improving college students' social-cognitive outcomes in STEM through a collaborative learning environment. Learning Environments Research. 2021;**24**:123-136

[14] Froehle CM, Roth AV. New measurement scales for evaluating perceptions of the technology-mediated customer service experience. Journal of Operations Management. 2004;**22**(1):1-21

[15] Ziegler R, Hamker N. The idea of a collaborative competition–a case study. Futures. 2011;**43**(4):441-449

[16] Chen S-Y, Liu S-Y. Reinforcement of scientific literacy through effective argumentation on an energy-related environmental issue. EURASIA Journal of Mathematics, Science and Technology Education. 2018;**14**(12):em1625

[17] Sanders ME. Integrative STEM Education as 'Best Practice'. Queensland, Australia: Griffith Institute for Educational Research; 2012

[18] Kelley TR, Knowles JG. A conceptual framework for integrated STEM education. International Journal of STEM Education. 2016;**3**(1):11

[19] N. R. Council. Monitoring Progress toward Successful K-12 STEM Education: A Nation Advancing? Canada: National Academies Press; 2013

[20] D'Angelo C, Rutstein D, Harris C, Bernard R, Borokhovski E, Haertel G. Simulations for STEM learning: Systematic review and meta-analysis, Menlo Park. SRI International. 2014;**5**(23):1-5

[21] Thibaut L et al. Integrated STEM education: A systematic review of instructional practices in secondary education. European Journal of STEM Education. 2018;**3**(1):2

[22] Sithole A, Chiyaka ET, McCarthy P, Mupinga DM, Bucklein BK, Kibirige J. Student attraction, persistence and retention in STEM programs: Successes and continuing challenges. Higher Education Studies. 2017;**7**(1):46-59

[23] Kyndt E, Raes E, Lismont B, Timmers F, Cascallar E, Dochy F. A meta-analysis of the effects of face-to-face cooperative learning. Do recent studies falsify or verify earlier findings? Educational Research Review. 2013;**10**:133-149

[24] Jeong H, Hmelo-Silver CE, Jo K. Ten years of computer-supported collaborative learning: A meta-analysis of CSCL in STEM education during 2005-2014. Educational Research Review. 2019;**28**:100284

[25] Laal M, Ghodsi SM. Benefits of collaborative learning. Procedia - Social and Behavioral Sciences. 2012;**31**:486-490

[26] Chen X, Soldner M. STEM Attrition: College Students' Paths into and out of STEM Fields (NCES 2014-001). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, US Department of Education; 2013

[27] Lichtenberger E, George-Jackson C. Predicting high school students' interest in majoring in a STEM field: Insight into high school students' postsecondary plans. Journal of Career and Technical Education. 2013;**28**(1):19-38

[28] Romash ZM. Leaving STEM: An Examination of the STEM to Non-STEM Major Change and How the STEM Curriculum Relates to Academic Achievement in Non-STEM Fields. Canada: Seton Hall University; 2019

[29] Gokhale A. Collaborative learning enhances critical thinking. Journal of Technology Education. 1995;**7**(1)

[30] Tolmie AK et al. Social effects of collaborative learning in primary schools. Learning and Instruction. 2010;**20**(3):177-191

[31] Esmonde I. Mathematics learning in groups: Analyzing equity in two cooperative activity structures. The Journal of the Learning Sciences. 2009;**18**(2):247-284

[32] Panitz T. Collaborative versus Cooperative Learning: A Comparison of

the Two Concepts Which Will Help Us Understand the Underlying Nature of Interactive Learning. 1999

[33] Goodyear P, Jones C, Thompson K. Computer-supported collaborative learning: Instructional approaches, group processes and educational designs. In: Handbook of Research on Educational Communications and Technology. 2014. pp. 439-451

[34] Lee VR, Drake JR, Thayne JL. Appropriating quantified self technologies to support elementary statistical teaching and learning. IEEE Transactions on Learning Technologies. 2016;**9**(4):354-365

[35] Pasani CF, Amelia R, Hassanhassan Z. Covid-19 impact in Indonesia's education sector: Challenges and strategy. Journal of Advanced Research in Dynamical and Control Systems. 2020;**12**(7 Special Issue):1722-1731. DOI: 10.5373/JARDCS/V12SP7/20202281

[36] Babaian T, Schiano B. Energize your Online Course with Group Work. In: HBP High. Educ. Inspiring Minds. 2020

[37] Singhal T. A review of coronavirus disease-2019 (COVID-19). Indian Journal of Pediatrics. 2020;**87**(4):281-286

[38] Barab S, Thomas M, Dodge T, Carteaux R, Tuzun H. Making learning fun: Quest Atlantis, a game without guns. Educational Technology Research and Development. 2005;**53**(1):86-107

[39] Cheng Y, Ye J. Exploring the social competence of students with autism spectrum conditions in a collaborative virtual learning environment–the pilot study. Computers in Education. 2010;**54**(4):1068-1077

[40] Tilak S et al. Multi-user virtual environments (MUVEs) as alternative lifeworlds: Transformative learning in cyberspace. Journal of Transformative Education. 2020;**18**(4):310-337

[41] Ketelhut DJ, Clarke J, Nelson BC. The development of River City, a multi-user virtual environment-based scientific inquiry curriculum: Historical and design evolutions. In: Designs for Learning Environments of the Future. International Perspectives from the Learning Sciences. 2010. pp. 89-110

[42] Gama K et al. Mapathons and hackathons to crowdsource the generation and usage of geographic data. In: Proceedings of the International Conference on Game Jams, Hackathons and Game Creation Events 2019. 2019. pp. 1-5

[43] Ibáñez MB, Rueda JJG, Maroto D, Kloos CD. Collaborative learning in multi-user virtual environments. Journal of Network and Computer Applications. 2013;**36**(6):1566-1576

[44] Hwang W-Y, Hu S-S. Analysis of peer learning behaviors using multiple representations in virtual reality and their impacts on geometry problem solving. Computers in Education. 2013;**62**:308-319

[45] Warburton S, García MP. 3D design and collaboration in massively multi-user virtual environments (MUVEs). In: Cases on Collaboration in Virtual Learning Environments: Processes and Interactions. United States: IGI Global; 2010. pp. 27-41

[46] Mantziou O, Papachristos NM, Mikropoulos TA. Learning activities as enactments of learning affordances in MUVEs: A review-based classification. In: Education and Information Technologies. United States. 2018;**23**:1737-1765

[47] Kuyath SJ. The Social Presence of Instant Messaging: Effects on Student

Satisfaction, Perceived Learning, and Performance in Distance Education. The University of North Carolina at Charlotte; 2008

[48] Rosé CP, Ferschke O. Technology support for discussion based learning: From computer supported collaborative learning to the future of massive open online courses. International Journal of Artificial Intelligence in Education. 2016;**26**:660-678

[49] Wang H-C, Rosé CP, Chang C-Y. Agent-based dynamic support for learning from collaborative brainstorming in scientific inquiry. International Journal of Computer-Supported Collaborative Learning. 2011;**6**:371-395

[50] Tegos S, Demetriadis S, Papadopoulos PM, Weinberger A. Conversational agents for academically productive talk: A comparison of directed and undirected agent interventions. International Journal of Computer-Supported Collaborative Learning. 2016;**11**:417-440

[51] Liu H, Spector JM, Ikle M. Computer technologies for model-based collaborative learning: A research-based approach with initial findings. Computer Applications in Engineering Education. 2018;**26**(5):1383-1392

[52] Angelaina S, Jimoyiannis A. Analysing students' engagement and learning presence in an educational blog community. EMI. Educational Media International. 2012;**49**(3):183-200

[53] Gressick J, Derry SJ. Distributed leadership in online groups. International Journal of Computer-Supported Collaborative Learning. 2010;**5**:211-236

[54] Le H, Janssen J, Wubbels T. Collaborative learning practices: Teacher and student perceived obstacles to effective student collaboration. Cambridge Journal of Education. 2018;**48**(1):103-122

[55] Rummel N, Mullins D, Spada H. Scripted collaborative learning with the cognitive tutor algebra. International Journal of Computer-Supported Collaborative Learning. 2012;7:307-339

[56] Bouyias Y, Demetriadis S. iArgue: A web-based argumentation environment integrating collaboration scripting support and flexible fading techniques. Educational Technologies for Teaching Argumentation Skills. Greece: Bentham Science Publisher; 2012:198-224

[57] Noroozi O, Weinberger A, Biemans HJA, Mulder M, Chizari M. Facilitating argumentative knowledge construction through a transactive discussion script in CSCL. Computers in Education. 2013;**61**:59-76

[58] Noroozi O, Biemans HJA, Weinberger A, Mulder M, Chizari M. Scripting for construction of a transactive memory system in multidisciplinary CSCL environments. Learning and Instruction. 2013;**25**:1-12

[59] Pifarré M, Kleine Staarman J. Wiki-supported collaborative learning in primary education: How a dialogic space is created for thinking together. International Journal of Computer-Supported Collaborative Learning. 2011;**6**:187-205

[60] Frisch JK, Jackson PC, Murray MC. WikiED: Using web 2.0 tools to teach content and critical thinking. Journal of College Science Teaching. 2013;**43**(1):70-80

[61] Bonney R et al. Citizen science: A developing tool for expanding science

knowledge and scientific literacy. Bioscience. 2009;**59**(11):977-984

[62] Brovelli MA, Ponti M, Schade S, Solís P. Citizen science in support of digital earth. Manual of Digital Earth. 2020;**18**:593-622

[63] Bereiter C, Scardamalia M. Knowledge building and knowledge creation: One concept, two hills to climb. In: Knowledge Creation in Education. Singapore: Springer Singapore. 23 May 2014. pp. 35-52

[64] Hong H-Y, Chen B, Chai CS. Exploring the development of college students' epistemic views during their knowledge building activities. Computers in Education. 2016;**98**:1-13

[65] Namdar B, Shen J. Intersection of argumentation and the use of multiple representations in the context of socioscientific issues. International Journal of Science Education. 2016;**38**(7):1100-1132

[66] Jiang S, Shen J, Smith BE, Kibler KW. Science identity development: How multimodal composition mediates student role-taking as scientist in a media-rich learning environment. Educational Technology Research and Development. 2020;**68**:3187-3212

[67] Jiang S, Shen J, Smith BE. Designing discipline-specific roles for interdisciplinary learning: Two comparative cases in an afterschool STEM+ L programme. International Journal of Science Education. 2019;**41**(6):803-826

[68] Altebarmakian M, Alterman R. Design heuristics to support cohesion within online collaborative learning groups. In: 2019 IEEE Frontiers in Education Conference (FIE). United States: IEEE; 16 Oct 2019. pp. 1-9

[69] Watkins J, Mazur E. Retaining students in science, technology, engineering, and mathematics (STEM) majors. Journal of College Science Teaching. 2013;**42**(5):36-41

[70] Tolentino L, Birchfield D, Megowan-Romanowicz C, Johnson-Glenberg MC, Kelliher A, Martinez C. Teaching and learning in the mixed-reality science classroom. Journal of Science Education and Technology. 2009;**18**:501-517

[71] Olsen JK, Rummel N, Aleven V. It is not either or: An initial investigation into combining collaborative and individual learning using an ITS. International Journal of Computer-Supported Collaborative Learning. 2019;**14**:353-381