Mathematical game-based learning: education students' collaboration and on-line experiences during disrupted Covid-19 circumstances

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ABSTRACT: The Covid-19 pandemic disrupted and forced universities to close and to change to on-line learning, in order to ensure the continuation of teaching and learning activities. Students had to embrace on-line learning despite their unpreparedness and the challenges thereof. This article reports on mathematics students' on-line collaboration on game-based learning. Participants were a cohort consisting of 52 Bachelor of Education mathematics students in their second year of study. They were randomly placed in groups, and had to interact on-line to create a board game on aspects of the intermediate phase of the mathematics curriculum. Each group submitted an explanation of their board game and a video on how the game works. Thereafter, students completed individual reflective narratives on their group collaboration and contribution of members. This was followed by individual task-based questions on the game by twelve selected participants. A deductive coding approach was followed to analyse the data. The findings revealed that students managed to collaborate and interact on-line despite their challenges.

INTRODUCTION

The outbreak of the Covid-19 pandemic in December 2019 changed the world dramatically and continues to spread across the globe [1]. This crisis has severely affected all facets of society on how people live and work. It also disrupted education and due to lock-down restrictions, universities closed. As a result, it was essential to continue with the intended teaching and learning activities, and education institutions required a transition to an on-line modality of teaching and learning [2]. Students had to embrace on-line learning despite their unpreparedness and the challenges thereof [1]. Moreover, Zoom, Microsoft Teams, Google Meet and other cloud-based video communication applications became a crucial platform for students to interact and collaborate in their learning endeavours [1].

As part of their course work, students in mathematics education had to work together on an open-ended task for grade 6 learners. The rationale was that they had to develop a class activity based on a specific mathematics topic, in a creative way, with the aim of promoting school learner's conceptual understanding. One strategy to achieve this objective is to integrate game-based learning (GBL) in assignments by creating, for example, a board game on a topic in the intermediate phase, grade 6 mathematics; namely, patterns, functions and algebra.

The task was initially planned for a face-to-face group activity in class; however, it had to be adapted for an on-line delivery mode due to the outbreak of the Covid-19 pandemic. Unfortunately, these students had no prior experience of collaborating on-line when working on an open-ended creative task in mathematics. They had to rely on one another and manage their own learning activities to address this challenge. Consequently, this article aims to determine how mathematics education students collaborated on-line in mathematical GBL by designing a board game for grade 6 learners.

THEORETICAL FRAMEWORK

The following theoretical aspects are outlined briefly below: game-based learning, mathematics board games and the solving of real-world problems, students' on-line collaboration and reflection on mathematics tasks.

Game-based Learning

As the focus of this article is on a mathematics board game, a key concept emanating from this is GBL. While most studies tend to focus primarily on digital GBL, an often-understudied part of GBL is physical artefact games, such as board games or card games [3]. Definitions of GBL mainly emphasise that it is a kind of game with specified objectives. GBL increases the ability and acquisition of game material and game playing, and gaming activity involves the resolution of problems, spaces and obstacles, providing players with a feeling of success [4].

Several scholars and practitioners have paid attention to GBL and problems solving skills. Considering the favourable benefits of games on learning from multiple studies, increasing numbers of researchers are dedicated to producing educational activities to enhance the student development of skills, especially to solve problems [3]. Several reasons why games are efficient for learning and the most often-cited attribute is the motivating purpose of games [3]. The idea is that entertainment games have been demonstrated to inspire the student to remain engaged for a long period of time through several motivating game elements. One of the main reasons for considering digital or physical games for learning, which is related to motivation, is the premise that it offers a variety of approaches to involve students in engaging gameplay [3].

The forms of participation that are carried out rely on design decisions that represent the distinct learning objective, learning characteristics and context. Since the notion of engagement is imprecise and understudied, the idea of engagement will be based on the Interact model of student activity [5], which distinguishes between cognitive engagement (mental processing and metacognition), affective engagement (emotional processing and regulation), and behavioural engagement (gestures, embodied actions and movement). The engagement of learners is made possible in part by the wide variety of methods to adapt, customise or personalise a game [6].

Adaptivity in a game enables each student to interact in a way that reflects his/her own circumstances [3]. This can be associated with the student's existing level of learning, cognitive skills, the emotions of the students or other factors. Further justification in favour of GBL is that it permits for failure, instead of portraying it as an unwanted result, a failure via design constitutes an essential and anticipated step towards learning [7]. The reduced effects of game failure promote risk-taking, hypothesising and investigation [8]. With the above-mentioned discussion on GBL, as well as the benefits of its use in a general sense, the focus will now be grounded within the mathematics subject and how GBL was utilised to form a board game.

Mathematics Board Games and the Solving of Real-world Problems

Mathematics is a fundamental subject in any education system. It gives useful information for everyday living and plays a significant part in human growth [9]. For many learners, unfortunately, mathematics is mostly a deterrent. Luhan et al demonstrate that mathematics is frequently categorised as unfavourable, since it is considered dull, difficult and worthless amongst learners [10]. GBL seeks to combat this perspective. Educators must design efficient ways to increase the interest of learners in mathematics, enhance their comprehension and strengthen their arithmetic abilities [9]. The challenging and quite often repetitive nature of the subject poses problems for learning mathematics for a large number of learners [11]. Educational board games can resolve these problems and influence mathematical learning and dispositions favourably.

Video and board games were utilised to enhance learner's mathematical performance in several fields, such as problem solving and algebra skills [12], critical-geometry skills [13] and arithmetic processes [14]. Although educational video games have been more popular over the last 20 years, empirical study on the impact of mathematical gaming on academic achievements of students remain inconclusive. However, this does not mean that GBL is completely ineffective when adapted for mathematics classrooms. The authors discovered that GBL is far more efficient than conventional teaching. Another area of concern is on how people collaborate on-line while working together on GBL and mathematical tasks, as outlined in the next section.

On-line Collaboration and Student Facilitation

Worldwide, university lecturers and teachers were forced to embark on on-line teaching and learning as a result of the Covid-19 pandemic [1]. It was expected that on-line learning would replace face-to-face classes to continue learning during the pandemic, as on-line learning platforms became the *modus operandi* for the delivery of subject matter, communication and the application of assessment practices [1]. Han et al highlight that effective facilitation through a learning management system (LMS) is essential for on-line classrooms as such an environment provides opportunities for students to engage actively in their learning, identify their own learning needs, manage learning responsibilities, reflect on their experiences and develop as self-directed learners [15]. Collaboration offers students communication opportunities and the benefit of assisting each other, and adds a social component to their learning [16][17]. d'Alessio et al found that, when facilitators provide a *supportive community* in an on-line environment and facilitate students' collaboration and involvement, students benefit from such interaction [18]. Berge distinguished different types of interaction involved in on-line tutoring to succeed; namely, pedagogical interaction (probe students for critical discussion), social interaction (promote learning, group members work cohesively and in a *mutual cause*), managerial interaction (management of learning), and technical interaction (software and technological aspects) [19].

Students' Reflection on Mathematics Activities

Reflection entails students' conscious thinking about, and analysis of, what they are doing or what they have done in a learning task and is related to metacognitive monitoring and regulation [20]. In general, metacognition involves planning and setting goals, conscious monitoring (awareness of why and how you are doing something) and regulation (deciding to do or adapt something) of a person's thought processes [21][22]. Furthermore, metacognitive activities

enable students to enhance their awareness about the best practices they can follow to learn more effectively and employ essential skills, such as critical and creative thinking, understanding and learning from failure, adaptability and personal responsibility [23]. In collaborative reflection, students interpret what they do and why they do it by involving themselves and others in conversation and debate to enhance their collective understanding [20]. Engaging students in reflection is a favourable pedagogical approach for supporting mathematics learning [24]. In their research, Calkins et al found that students who participated in reflection in an on-line learning environment, seemed to be well engaged, serious in answering the questions and their confidence levels increased over time [25]. In mathematics, students should be guided to think about mathematics and judge themselves in terms of their abilities, their strengths and weaknesses [24].

Since this study focused on GBL in mathematics, it seeks to ameliorate this gap in the literature. The following question directed the research: how do mathematics education students collaborate when designing a board game on-line?

RESEARCH CONTEXT AND METHODOLOGY

Research Context

This research was part of a South-African University Scholarship of Teaching and Learning (SoTL) project to expose mathematics education students to problem-based learning (PBL) contexts and real-world tasks, with the aim of developing collaborative and self-directed learning abilities. Although this project involved both quantitative and qualitative aspects, this article reports only on the qualitative approach; namely, students' on-line collaboration in creating a board game for grade 6 learners based on a topic from the mathematics curriculum. The PBL task was related to the content of a mathematics course in the intermediate phase; namely, number patterns, algebraic reasoning and functions. The study was initially planned for a face-to-face learning modality; however, it had to be adapted for an on-line mode of delivery due to the outbreak of the pandemic. All the activities were done on eFundi, the LMS of the University. This research has a social-constructivist stance. Mabley et al emphasise that active learning approaches, such as PBL, are based on the social-constructivist views where students solve problems collaboratively and work together on ill-structured problems [26].

Participants and Ethical Aspects

The population comprised a cohort consisting of 52 registered Bachelor of Education mathematics students in their second year of study at the Faculty of Education. The researcher randomly grouped students of four members per group with a total of 13 groups. Each group selected a leader for the duration of the project. It was expected of members to give reasons for their choice of a leader, and this was done on-line on a Google Form. Reasons included aspects, such as a hard worker, a good leader that takes initiative, a delegate, diligent, punctual person and a good communicator. The group leaders had to manage the group activities, ensure the collaboration of every member and had to upload the respective assignments on-line. The project was approved by the Scientific Committee of the Research Unit for Self-Directed Learning, the Education Faculty Ethics Committee and the University Research Data Gatekeeper Committee. All students completed informed consent on-line. During the project, all ethical guidelines and requirements were adhered to.

Group Collaboration and Communication

Due to the pandemic, the course was offered on-line during the second semester of 2020. Initially, each student had to do research on PBL, active learning and cooperative learning (CL), and then submit an assignment based on these topics. The aim was to introduce these strategies to students prior to their group work. As part of group work, members had to work on the tasks, where they shared responsibility, accountability, knowledge and skills. Group members could choose their own ways of communication. They mainly used email, WhatsApp, Telegram, Facebook and Zoom. The researcher communicated with the whole class to support and facilitate students.

In addition, each group leader created a WhatsApp or Telegram group as a platform to enable direct and effective communication between the members and to create opportunities for them to support each other. They decided on an approach as to how they would go about sharing information on the board game and their reflections on-line with each other. In their groups, students first decided on a theme for their board game and how it should work. Each group member could decide on the part that he/she wanted to do, and then distribute the work among themselves (make the playing board and cards, dice, video or compile the document on their game). They set due dates and tried to adhere to submitting their games on time. In addition, the students had to ensure that they understood and interpreted the content as set out in the mathematics curriculum.

Designing a Mathematics Board Game and Student Activities

The scenario was formulated as follows: the principal is aware of GBL that can be integrated to make mathematics more meaningful to learners. He asked you to give a presentation to your fellow mathematics colleagues on the integration of GBL, since some students are struggling with mathematics. You have decided to design a board game to

assist learners in the understanding of concepts relating to patterns, functions and algebra for grade 6. The purpose of this task was to expose learners to, and engage them in, the learning content in a creative manner. Requirements for developing a board game are summarised in more detail:

- Design a board game that is applicable to the learning content for grade 6 regarding the mentioned topics. Everything you need for the game must be made yourself; for example, dice, cards and a creative board. The board must be decorated according to the mathematics topics addressed.
- At least 25 cards with questions/activities must constitute part of the board game.
- Four learners must play the game, and it must be aimed at enhancing their mathematical learning.
- The board game and all of its components must be in a container you made yourself. The name of the board game must appear clearly on the container. Designed items should be environmentally friendly wherever possible.

Furthermore, students had to clearly indicate how their game is aligned with the mentioned topic. Each group had to submit a PDF, Word document or a PowerPoint presentation with an explanation of the game, the rules and the procedures to be followed. Finally, students had to make a video of no longer than eight minutes, in which they could explain and demonstrate their game and discuss its appropriateness according to the content of the subject. The value of the video was to provide some additional evidence regarding students' collaborative effort to develop the mathematics board game and illustrated how the game works. Each group leader had to upload the solutions.

The on-line marking tool of the University was used for assessment and the first author used a rubric for assessing the board game. The following ten criteria were used to assess student's board game: the introduction, objectives, content of the game, compliance with the instructions, adherence to the requirements, the game board, playing cards, to determine students' creativity, correct application to link the topic to the course content, and finally the technical care of the board game. The mark obtained was part of the course mark of students. It must be noted that the aim was not to compare the board games of the different groups, and as such, each board game was assessed on its own merit.

The researcher randomly selected 20 students to complete individual task-based questions on a Google Form. Students had to reflect on the nature of their collaboration in terms of the support from their group members, their responsibility, personal interaction and communication, the challenges that they experienced and how they managed it. Moreover, they had to award a mark out of 10 for themselves, as well as for each of the group members regarding their active participation and contribution to the group. Unfortunately, only 12 students completed these questions because the semester ended. An example of a mathematics board game is shown in Figure 1 below. The figure displays the components of the board game of Group 5, which they named No Mistakes Snakes. The objectives with their game were that learners should recognise patterns, describe general rules or relationships of patterns, and calculate the input and output values of a given pattern.

Figure 1: An example of a mathematics board game (Group 5).

Some examples of questions on their playing cards are the following:

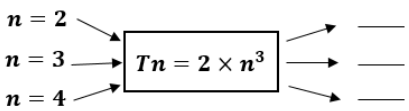

Figure 2: Complete this flow diagram.

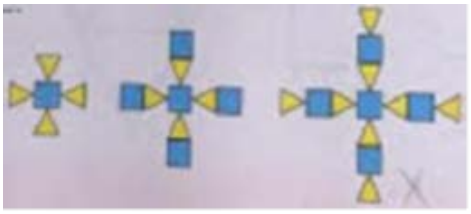

Figure 3: Explain what happens in this pattern.

Data Collection

Documents from each group, as well as individual member's data were gathered as shown in Table 1 below.

Table 1: Data collection methods.

1. Documents from each group	a) PDF, Word document or PowerPoint regarding all details of each game (13 documents) b) Videos of each group (13 videos)
2. Individual member's data	c) Individual reflective narratives on the collaboration and contribution of the group members (52 reflections) d) Individual task-based questions on the game of selected participants (12 answer sheets)

Data Analysis

The first researcher analysed and manually coded the data. A deductive coding approach was followed. The researcher approached the data with a prior developed set of codes related to the research question and searched for ideas or concepts in the text. Group documents were also analysed to determine students' approaches, activities and board game experiences. The initial codes that emerged from the literature were group work, collaboration, communication, interaction, planning, challenges, support, reflection, mathematics knowledge and skills, feelings, and resources. Codes were categorised and some themes emerged.

RESULTS AND DISCUSSION

The following themes emerged; namely, approach and resources, collaboration and interaction, mathematics knowledge and skills, and reflection and challenges. Table 2 presents the responses of some of the participants on their collaboration. The square brackets, for example (P1), indicate the participant number.

Table 2: Exemplars of student responses on their collaboration when designing a board game.

Theme	Exemplars of student responses
Approach and resources	We first looked at the curriculum document to see which content we can change into a board game - (P16) We had to make sure that we understand patterns, functions and algebra, and that we know how to teach this in a classroom - (P24) We first decided about the theme of our game and how it should work - (P8) We looked at other board games that are currently on the market to get an idea of what is expected - (P21) I tried to ask people about different board games they know, and I searched the games on Google Play store and tried to play them for example *Ludo King Game* - (P45) We consulted YouTube, where we had technical difficulties in making an audio for the video which we were using to explain the game - (P23)
Collaboration and interaction	We first distributed the work among us - (P27) Our group communicated about the task from the beginning, each person decided on which part he/she wanted to do long before the due date - (P36) There was good communication between the group members before, during and after the task. We got along well and formed a good bond between us - (P47) …everybody answered or reacted quickly if something was asked or discussed - (P14) The communication in our group was really poor. Members sent each other personal messages all the time causing the others not to know what is going on - (P52) The only problem I experienced was miscommunication between members, but it was fixed quickly - (P38) Creating the Zoom meeting was the most imperative part to share or to communicate about the game - (P47) The group work reduced the workload tremendously and we could build on each other's ideas - (P31) Our group worked together very well. We respected each other's ideas, and we were not envious if another member had a better idea - (P6) We as a group planned clear due dates to complete the task on time. We kept to these due dates - (P13) The game was completed in time, but we feel that we could have made a better game if we planned better - (P1) We were able to address the task effectively because we helped one another to understand it and to complete it to the best of our abilities - (P19) Everybody completed their components well and kept to the theme. There was no conflict, and everybody listened to each other's opinions and ideas and discussed them - (P46)

Mathematics knowledge and skills	We used problem-solving skills to analyse the problem, as well as communication skills to share ideas to my group members - (P25) We used our knowledge on input and output values. This made the task easier and more appropriate - (P52) I mainly used problem solving and logical thinking. Basic algebra was also used to figure out what to put on the board - (P41) I used basic mathematical skills since it was supposed to be a game that learners will be able to play immediately - (P45) We used reasoning, guess-and-check and tabulating - (P7)
Reflection and challenges	We enjoyed working together because the others can help, and their ideas help you to grow your own ideas - (P34) We really enjoyed the end results - (P30) I could see my own mistakes and improve, so that I can build my own knowledge - (P28) I really enjoyed it to design the playing cards and the board game because I could think about creative ways to transfer the content - (P52) The reflection was good because I could identify the group members who did not work, and I could identify problem areas - (P1) I think group assignments are good if you are paired with people who are willing to communicate and work together - (P22) I personally did not think that I would be able to make a board game based on maths - (P37) I enjoyed it to design the board game. I was inspired by the interests of the learners whom I home-school now - (P41) Reflection helped us because we continuously checked if our idea would work. If it does not work, we could make improvements - (P4) Although group work has its own challenges, two heads are always better than one. It was good to get the inputs of various group members - (P25) A challenge was to find suitable problems for the playing cards - (P10) The fact that we were not together was a tough hurdle to overcome - (P11) Integrating the maths learning content in the game was a huge challenge - (P52) It was a challenge to create playing cards that are challenging to the learners, but not impossible to let the game *flow* - (P37) It was difficult to find the correct game that the learners can play and will enjoy - (P28) It was a challenge for us to create the video on our game - (P33) To find a time when everybody can talk together and share their ideas - (P43) Since we are not around the campus due to Covid-19, most of us were struggling with Internet connection - (P36) The assignment was challenging as it required us to be more creative - (P51) Our board game was already designed when we realised that it was not based on the prescribed topic. We had to start all over again - (P45) The challenges we faced were how to make the video as we could not do the Zoom meeting due to the connectivity problems. At the end of the day, we overcame these challenges and came up with a plan that worked perfectly fine for us - (P5)

The attempt in this section was to answer the research question: how do mathematics education students collaborate when designing a board game on-line?

Keep in mind that this PBL task was initially planned for a face-to-face teaching-learning context, but had to be executed on-line due to the pandemic. Students' interaction was primarily on two of the three levels described by the Interact model of activity [5]; namely, cognitive engagement and affective engagement. Examples of cognitive engagement are the following: they had to study number patterns, algebra and functions and prepare suitable questions for the playing cards. Students had to use their problem solving and algebra skills and perform arithmetic processes [12][14] to develop the playing cards. Two students reflected that integrating the mathematics content into the game was initially a challenge (P52) and they identified some personal limitations. However, it also provides the opportunity to grow and develop skills to be a leader of the group (P50).

Examples of affective engagement involve students that were dependent on each other to succeed as a group (P19). They shared different responsibilities to plan the game and eventually develop the final product (P46). Students realised that planning a task, setting due dates and adhering to them are important to succeed (P13). Furthermore, members learned to collaborate, communicate on-line and had critical discussions about the mathematics topics. Most of the group members worked well together, they listened to different opinions (P46), and respected each other's ideas (P6, P31, P46).

Group members were actively involved in GBL. The value of designing the game was that students had the opportunity to present the content in a creative and playful manner to make mathematics more meaningful to the learners.

The students also developed communication and collaborative skills in their respective groups. Examples of social and pedagogical interaction [19] were indicated, where members responded quickly, answered questions and supported each

other (P14, P47). Students were in contact throughout the design process, despite working on-line. They monitored their progress and constantly checked if their ideas would work, else they suggested some changes to improve the game (P45, P28).

Unfortunately, some of the groups experienced challenges with communication (P38, P52) and did not necessarily make time to share their ideas (P43). Other challenges were poor Internet connection (P36) and some students struggled to create a video of their board game (P33). Group 45 realised that their board game was not based on the required topic, and they had to start all over again. The initial plan was for students to allow grade 6 learners to play their board game to determine its effectiveness or shortcomings and then improve the game, if necessary. However, due to the pandemic, this was not possible. Alternatively, students were requested to play their game with their family members to get their feedback.

Some recommendations include the following: students must have clear guidelines about what is expected of them in terms of their interaction and collaboration without suppressing their creativity; they must provide regular feedback to the lecturer on their progress and challenges while working on a task and the assessment procedures must be clear.

CONCLUSIONS

Collaborating on-line during the pandemic was challenging, as students were mainly used to a face-to-face class environment. Designing the board game was challenging since members were dependent on each other for the success of their group. Despite some challenges, each group managed to create an interesting and functional board game.

Group members shared their responsibilities on-line by dividing the tasks among them, communicating regularly about their progress, interacting as needed, and reflecting positively on their experiences. However, some groups experienced challenges related to communication and members' contribution to group work, as well as some Internet connection problems that complicated on-line meetings. Eventually, students overcame these challenges and devised a plan that worked well for them. In general, on-line collaboration seems to have made a valuable contribution to the learning and success of these students.

Possible limitations of this research are that the researcher did not monitor the progress of the students while designing their games. In addition, students had to work on-line with members that they did not know or who did not contribute as expected of them.

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REFERENCES

1. Mishra, L., Gupta, T. and Shree, A., Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. *Inter. J. of Educational Research* (2020).
2. Bryson, J.R. and Andres, L., Covid-19 and rapid adoption and improvisation of online teaching: curating resources for extensive versus intensive online learning experiences. *J. of Geography in Higher Educ.*, 44, **4**, 608-623 (2020).
3. Plass, J.L., Homer, B.D. and Kinzer, C.K., Foundations of game-based learning. *Educational Psychologist*, 50, **4**, 258-283 (2015).
4. Beserra, V., Nussbaum, M., Zeni, R., Rodriguez, W. and Wurman, G., Practising arithmetic using educational video games with an interpersonal computer. *Educational Technol. & Society*, 17, **3**, 343–358 (2014).
5. Domagk, S., Schwartz, R.N. and Plass, J.L., Interactivity in multimedia learning: an integrated model. *Computers in Human Behavior*, 26, **5**, 1024-1033 (2010).
6. Aziz, E-S., Esche, S.K. and Chassapis, C., An interactive game-based engineering laboratory. *World Trans. on Engng. and Technol. Educ.*, 8, **2**, 131-136 (2010).
7. Kapur, M. and Bielaczyc, K., Designing for productive failure. *J. of the Learning Sciences*, 21, **1**, 45-83 (2012).
8. Hoffman, B. and Nadelson, L., Motivational engagement and video gaming: a mixed methods study. *Educational Technol. Research and Develop.*, 58, **3**, 245-270 (2010).
9. Kiili, K., Devlin, K., Perttula, A., Tuomi, P. and Lindstedt, A., Using video games to combine learning and assessment in mathematics education. *Inter. J. of Serious Games*, 2, **4**, 37-55 (2015).
10. Luhan, J., Novotna, V. and Kriz, J., ICT support for creative teaching of mathematic disciplines. *Interdisciplinary Studies J.*, 2, **3**, 89 (2013).
11. Stewart, J.R. and Agah, A., Teaching a software engineering course on developing video games: a Unified Process versus Extreme Programming. *World Trans. on Engng. and Technol. Educ.*, 10, **1**, 6-12 (2012).
12. Bottino, R.M., Ferlino, L., Ott, M. and Tavella, M., Developing strategic and reasoning abilities with computer games at primary school level. *Computers & Educ.*, 49, **4**, 1272-1286 (2007).
13. Yang, J.C. and Chen, S.Y., Effects of gender differences and spatial abilities within a digital pentominoes game. *Computers & Educ.*, 55, **3**, 1220-1233 (2010).

14. Moreno, R. and Duran, R., Do multiple representations need explanations? The role of verbal guidance and individual differences in multimedia mathematics learning. *J. of Educational Psychology*, 96, **3**, 492-503 (2004).
15. Han, S.J., Lim, D.H. and Jung, E., A collaborative active learning model as a vehicle for online team learning in higher education. *Research Anthology on Developing Effective Online Learning Courses*, 217-236 (2021).
16. Jacobs, G.M. and Ivone, F.M., Infusing cooperative learning in distance education. *The Electronic J. for English as a Second Language*, 24, **1** (2020).
17. Loh, R.C.Y. and Ang, C.S., Unravelling cooperative learning in higher education: a review of research. *Research in Social Sciences and Technol.*, 5, **2**, 22-39 (2020).
18. d'Alessio, M.A., Lundquist, L.L., Schwartz, J.J., Pedone, V., Pavia, J. and Fleck, J., Social presence enhances student performance in an online geology course but depends on instructor facilitation. *J. of Geoscience Educ.*, 67, **3**, 222-236 (2019).
19. Berge, Z.L., Facilitating computer conferencing: recommendations from the field. *Educational Technol.*, 35, **1**, 22-30 (1995).
20. Chang, B., Reflection in learning. *Online Learning*, 23, **1**, 95-110 (2019).
21. Desoete, A. and De Craene, B., Metacognition and mathematics education: an overview. *ZDM*, 51, **4**, 565-575 (2019).
22. Lee, N.H., Ng, K.E.D. and Yeo, J.B.W., *Metacognition in the Teaching and Learning of Mathematics*. In: Toh, T.L. (Ed), Mathematics Education in Singapore, Mathematics Education - an Asian Perspective. Singapore: Springer Nature Singapore, 241-268 (2019).
23. Daradoumis, T. and Arguedas, M., Cultivating students' reflective learning in metacognitive activities through an affective pedagogical agent. *Educational Technol. & Society*, 23, **2**, 19-31 (2020).
24. Choi, J., Walters, A. and Hoge, P., Self-reflection and math performance in an online learning environment. *Online Learning J.*, 21, **4**, 79-102 (2017).
25. Calkins, S., Grannan, S. and Siefken, J., Using peer-assisted reflection in math to foster critical thinking and communication skills. *Primus*, 30, **4**, 475-499 (2020).
26. Mabley, S., Ventura-Medina, E. and Anderson, A., *I'm lost* - a qualitative analysis of student teams' strategies during their first experience in problem-based learning. *European J. of Engng. Educ.*, 45, **3**, 329-348 (2020).