PROMOTING STUDENTS’ CRITICAL THINKING & PROBLEM SOLVING SKILLS VIA MOBILE-SUPPORTED LABS

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ABSTRACT

Critical Thinking & Problem Solving belong to 21st century skills that enhance ways of thinking, learning, working and living in the world. When combined with well-designed educational activities, mobile technology has the capacity to foster these abilities. This study evaluates the Critical Thinking & Problem Solving skills of ninth-grade students who participated in mobile-supported labs. According to the findings of a questionnaire provided to students, their skills have improved. Students' written responses to open-ended questions before and after the mobile-supported Labs revealed interesting data about their improvement. Also, records of students’ written discussions on the Viber-platform, throughout the process, revealed aspects of critical thinking & Problem Solving development.

KEYWORDS

Mobile Technology, Critical Thinking, Problem-Solving, Greece, Secondary Education

1. INTRODUCTION

Critical thinking is a reasonable, reflective, responsible, and skilled thinking process that focuses on what to believe and do (Cavus & Uzunboylu, 2009). As a result of metacognition, students who can monitor and evaluate their own cognitive processes are more likely to exhibit high-quality thought. When students think critically, they assess the outcomes of their thought processes, such as the quality of a decision or the effectiveness of a Problem-Solving strategy (Halpern, 1998). Problem Solving in the context of education refers to the capacity of students to detect problems, obtain and evaluate pertinent information, develop solution strategies, propose alternative and viable solutions, solve problems and communicate the solutions (Hwang et al., 2018; OECD, 2005). Critical Thinking and Problem Solving skills, along with other skills belong to the 21st century skills that students must master to compete in the workforce of the future.

Mobile learning can engage students in experiential and situated learning without location or time constraints and can enable them to continue learning activities begun inside or outside the classroom through contextual engagement and communication with them and/or teachers. In addition to supporting on-demand access to educational resources independent of students' commitments, mobile technology can facilitate the acquisition of new skills or knowledge (Sharples et al., 2009). Technology can improve students' higher-order cognitive skills, such as Critical Thinking. As critical thinking is a crucial ability for modern students, teaching and learning tools must be able to promote its growth. Mobile technology may help to address this challenge. The virtual engagement of pupils in information retrieval alters both their cognitive processes and mental states. The ability of mobile technology to improve students' Critical Thinking motivates them to become more developed and contemporary individuals (Ismail et al., 2016). By communicating at their own convenience via mobile technology, passive students may become more engaged in class. Mobile devices can enhance their experiences by promoting the reflection required for effective communication and critical thought. Through texting, phone, video, social networking, and other internet technologies, mobile learning may help promote students' critical reflection with others. Students are able to record their thoughts, observations, and activities on mobile devices for instant or later analysis and evaluation. This skill provides a routine and time for reflection, which may lead to a shift in viewpoint and the development of creative and critical thought (McCann & Camp, 2015). Interventions in education that utilise these mobile capabilities go beyond information delivery to develop a platform that decreases the negative effects of time lag and promotes critical thought. Mobile technology permits the creation of new educational models (Fisher & Baird, 2006). In addition, students can utilise mobile devices to improve their graphic representation and critical thinking skills (Saputra & Kuswanto, 2019). Mobile technology is an effective learning medium that helps students to study anywhere and at any time, improves the learning process, and facilitates the mobility of equipment. It has been demonstrated that mobile technology facilitates student engagement in creative, collaborative, critical, and communicative learning activities in science education (Cavus & Uzunboylu, 2009; Saputra & Kuswanto, 2019).

However, mobile technology alone cannot guarantee the efficacy of learning; rather, the success of learning is partly decided by a mobile-based learning process. If mobile technology is used simply to memorize information searches and teachers fail to establish an appropriate teaching method to be used in conjunction with the technology to enhance students' critical thinking, the potential of the technology is lost. Teachers must thus create a class that incorporates mobile technology in a way that not only attracts and motivates students, but also leads to a more meaningful learning experience that improves students' higher-order thinking, particularly their critical thinking (Ismail et al., 2016). In addition, the integration of technology and well-designed educational activities makes the transfer of knowledge and skills across settings and life transitions feasible (McCann & Camp, 2015).

This study claims that well-designed, technology-enabled learning environments provide valuable chances for reflection and critical thinking. The chosen instructional strategy is an inquiry-based approach, which shifts the emphasis of science education from traditional memorization of facts and concepts in separate specific disciplines to inquiry-based learning in which students are actively engaged in using both science processes and critical thinking skills as they seek answers (Zacharia, 2003). Not only does requiring students to undertake original research strengthen their critical thinking in respect to their own work, but it also increases research outputs generally. Research experience boosts students' awareness of how evidence may be used to demonstrate a certain opinion and improves their comprehension of newspaper and website material. Instead of accepting results at face value, they submit questions for data analysis, which significantly increases their engagement in the learning process (Wyatt, 2005).

The importance of investigating the development of Critical Thinking and Problem Solving skills through mobile-supported Labs stems from the correlation between the findings and classroom practices. Critical thinking and Problem Solving skills are usually assessed by using a pretest/post-test quasi-experimental design (Zheng et al., 2016), by using the independent–sample t–test in a large sample (Lai & Hwang, 2014), by administering semi-structured interviews, by doing class observation or a combination of these methods (Agustina et al., 2022). Surveys address either the dispositional dimension of critical thinking (ex. the California Critical Thinking Disposition Inventory – CCTDI, e.g. Unlu & Dokme, 2017), or the actual skills dimension (ex. the California Critical Thinking Skills Test – CCTST, e.g. Stephenson et al., 2019). Although worldwide research has been undertaken on the relationship between mobile technology and critical thinking, the cultural background of each country may impact the findings. In addition, in Greece mobile learning is an underexplored topic and the development of higher-order thinking skills is weak. Consequently, the present research, which was done in Greece, adds to worldwide research, and the findings are anticipated to have significance for researchers and school policymakers.

In this work, students' Critical Thinking and Problem-Solving skills development via mobile-supported labs is investigated. The research question was: *How Critical Thinking & Problem-Solving Skills are evaluated in a mobile-supported Lab sequence and to what extent the Post-Lab Viber communication contributes?*

2. METHOD

2.1 The Sample

This study was conducted in a Junior high school in Kavala, Greece, during the second semester of the academic year 2021-22. The sample consisted of 10 ninth graders (15 years old) who willingly participated in the school's science club. The science club members met once a week after school hours. One of the authors of this study, who also taught science to the pupils, formed this group. Four females and six males with high Physics grades participated in a mobile-supported Lab sequence. The students were skilled with their smart phones but had never been engaged before in mobile learning activities.

2.2 Design of the Lab Sequence

The Lab sequence consists of 4 topics, namely Hooke's Law, Linear Oscillator, Pendulum and Friction. Each topic has 4 experimental (Lab) sessions: familiarize, explore, extend and reflect. Each Lab session lasts one week. Thus, the whole Lab sequence lasted 16 weeks. Each Lab has three phases (pre-Lab, in-Lab, post-Lab). The unfolded structure of the Lab sequence is depicted in Figure 1.

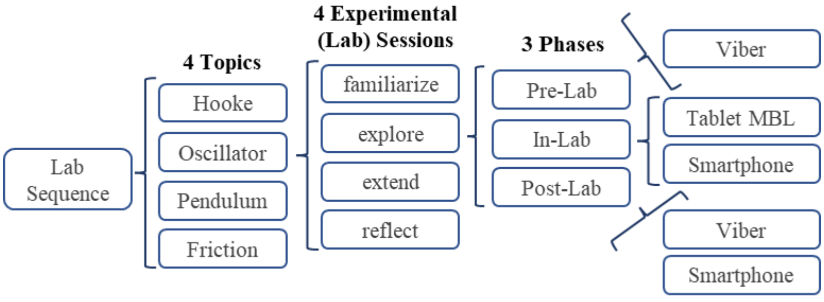

Figure 1. The unfolded structure of the Lab sequence

A short description of the 4 Lab sessions of each topic is as below:

- *familiarize*: Basic theoretical notions are discussed. The students become familiarised with the measurement setup (ex. first glance of elongation - weight)
- *explore*: The basic parameters that affect the experimental result are investigated (ex. spring stiffness, hanging weight)
- *extend*: An exploration of extended features takes place (ex. 2 springs in series/parallel)
- *reflect*: The students reflect on the concepts, the experimental procedures, the way that evidence can be drawn from graphs, the reliability of the measurements, the communication of the findings etc.

A short description of each phase in each Lab session is as below:

- *pre-Lab*: A captivating scenario is provided to spark conversation regarding the inquiry procedure. The students fill an Experiment Design Plan sheet. Questions are asked to promote critical thinking, such as "What are we investigating?", "What is our hypothesis?", "How will we construct an experiment?", and "How will we test our hypothesis?".
- *in-Lab*: The experiment is carried out using wireless sensors and tablets as Microcomputer-based Laboratories (MBL). The students monitor the evolution of relative dynamic diagram representations in their smartphones/tablets via shared session affordance of SPARKvue software. The monitoring takes place in-class or from home for the students who are unable to physically attend the lab owing to an unusual circumstance, such as illness.
- *post-Lab*: Analysis of the results takes place and a reflective procedure about the whole Lab sequence is applied. The students complete a Reflective Experiment Design Sheet. Indicative questions for promoting critical thinking are "What did we investigate?", "What was our hypothesis?", "How was our hypothesis verified?". Students also reflect on the data provided from graphs.

2.3 Implementation of the Lab Sequence Utilizing Mobile Devices

Nowadays, the extensive use of mobile devices has replaced the typical Laboratory equipment in a modern classroom. Actions that in the past years were typically carried out by a computer, are now being performed by a tablet. The use of wireless sensors has eliminated the need for the interface through which older days wired sensors were connected to the computer.

In our Lab sequence, we used both conventional laboratory equipment (springs, weights, bases, clamps, etc.) and mobile technologies (PASCO Force Acceleration Sensors and SPARKvue software on school tablets). Wireless Force Acceleration Sensors monitor force, acceleration, and rotational velocity. These devices link with PASCO SPARKvue suite software through bluetooth for data logging on tablets/smartphones

(SPARKvue, 2014) and visualize data in many ways (graphs, tables, numeric indicators, etc). Students can monitor the evolution of the experiment on their smartphone screen through the *Shared Session* affordance, which also saves the experiment individually so that the data be analyzed afterward. Figure 2 illustrates a smartphone display during the oscillation experiment. Three student groups are connected to a shared session to obtain real-time data and its accompanying graph. One student, who is not physically present in the school laboratory and is connected from home, has the opportunity to observe the experiment, the data-logging diagram and to acquire the experimental data.

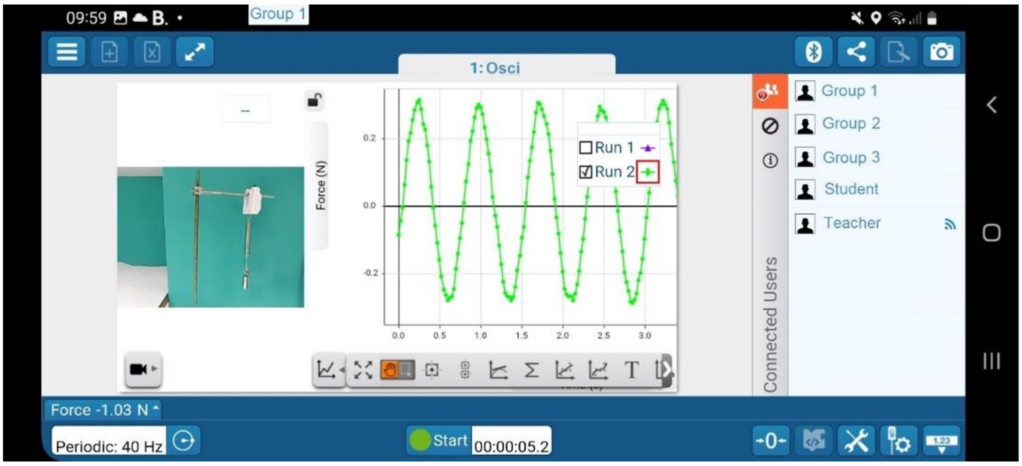

Figure 2. PASCO SparkVue datalogging software shared session

Students also used their smartphones for both student-to-student and student-to-teacher communication and reflection on the experimental procedure. This was accomplished by forming a Viber group, which provided students with an extra channel for information, communication, and cooperation via their smartphones, also outside the classroom environment. A brief description of the utilization of the mobile devices in each phase of the Lab sessions, as depicted in Figure 1, is as below:

- *pre-Lab phases:* The Viber group was employed for discussions on the science club's procedures and the planning and resolution of relevant questions. Thus, during the Labs the participants had more time to focus on issues related to the experimental process. In several circumstances of student absence, links to distance learning platforms (Zoom/Webex) and reports to be completed were distributed through the group to facilitate the active participation of absent students.
- *in-Lab phases:* The tablets were utilised as MBLs for diagram generation and study. Concerning the diagrams resulting from the experimental data, contentious debates between the students were held. In addition, share session affordance and/or a tablet camera were utilised for students' active involvement in distant experiments using their mobile phones.
- *post-Lab phases*: The Viber group was used to settle questions regarding student assignments or charts to be processed, to transmit diagnostics to be filled as reflective, and to resolve questions. In addition, methods of disseminating the findings to the larger scientific school community were discussed. In addition, the students' mobile phones served as MBLs, as the data and diagrams from the experiments were recorded on them for additional examination at home. Lastly, cell phones were utilised to capture the procedure for use in presentations and conferences.

Students worked in groups of three or four and were supported by worksheets. The four topics of the Lab sequence were structured using the same inquiry-based learning framework according to Pedaste et al. (2015). In each Lab, the students were oriented through a story based on everyday life, developed testable questions, formulated hypotheses about the probable answers, designed and conducted experiments to test their hypotheses, analyzed and evaluated the data, drew conclusions, and communicated their findings to the class, receiving feedback and review from their classmates. Although reflection occurred throughout the whole procedure, students reflected on the entire Lab during the final reflect session. They also completed a Reflection Report at home during the entirety of the Lab session using their smartphones.

2.4 The Measuring Instruments

To address the research question, two methods have been employed, namely, the evaluation of the students' Critical Thinking & Problem Solving skills, and the analysis of the messages exchanged in the Viber group, during post-Lab sessions. For the evaluation method, both the students' Critical Thinking & Problem Solving skills have been assessed, as well as the students' perceptions as a self-evaluation process on these skills have been examined.

The instrument for the self-evaluation is based on a questionnaire devised by Hwang et al. (2018). The original questionnaire consists of 23 questions-items that are organized into 4 skill areas (4Cs), namely, collaboration, communication, creativity, and critical thinking & problem-Solving. In our study, only items about Critical Thinking & Problem-Solving skills are analyzed (Appendix A).

Two experienced secondary school teachers, a physics teacher and an English teacher, acted as translators for the translation and adaption of the questionnaire into the Greek language. The translators were native English and Greek speakers who collaborated by discussing the precise phrasing of each question until consensus was reached. The translated questionnaire was reviewed by a small group of five ninth-grade students for semantic accuracy. Each question was read aloud, and the students were then instructed to explain in their own words what they had understood from each question. This approach resulted in some question rephrasing. An experienced Greek language instructor examined the final version of the questionnaire for syntax and spelling. Prior to and following the entire Lab sequence, the final form of the questionnaire was distributed to the science club students.

Before and after completing the Lab Sequence, students were required to answer a set of open-ended questions forming the assessment tool. Appendix B's open-ended questions were based on the topics addressed in the questionnaire in an effort to undertake a more in-depth analysis. The content of the students' free-form written responses was analysed by two authors of this research. Inter-rater reliability of 0.90 was achieved when two researchers separately categorised pre- and post-test student responses and then engaged in a lengthy discussion to resolve any inconsistencies.

Moreover, recordings of students' written dialogues on the Viber platform were evaluated to detect critical thinking and problem solving characteristics. Ethical issues were taken into account according to the new General Data Protection Regulation. The questionnaires were anonymous. Both the school board and the students were notified that all data gathered from the surveys and the Viber group will be utilised only for research purposes.

3. RESULTS AND DISCUSSION

3.1 Analysis of the Post-Lab Viber Communication

Apart from the messages of social type ("hello", "how are you", etc.) a total of 1046 messages referring directly to the Lab activities were exchanged in the Viber group, during the four-month operation of the science club. Viber messages were classified into four categories depending on the content of their discussions: (a) procedural issues, (b) Lab homework, (c) Connectivity issues and (d) Discussion for motivation purposes. 48% of the total 1046 messages refer to Procedural issues, 36% to Lab homework, 3% to connectivity issues and 13% is devoted to motivation purposes. *Procedural issues* concern in discussions of a procedural nature pertaining to the running of the science club, including changes to the meeting schedule, absences, student assignments etc. *Connectivity issues*, such us sending links of distance learning platforms for students that could not participate face to face in the Labs. *Discussion for motivation purposes*, refers to messages between the teacher and the students to cultivate a pleasant context, enhance active participation, engagement and encouragement. Finally, *Lab homework messages* concern on reflective debate between students for the completion of the assignments in the post-lab phase of each Lab. Students in their messages look for evidence in the graphs, consider other interpretations in data analysis, participate in reflective discussions about the experiments and come up with solutions in challenging situations in the experimental setups. Analysis of the Viber-message threads have shown that students seem to examine the "big-picture", avoid emotional reasoning or oversimplifications, question the conclusions and understand the problem they are dealing with. Such items are indicative of the evolution of students' critical thinking & problem-solving skills.

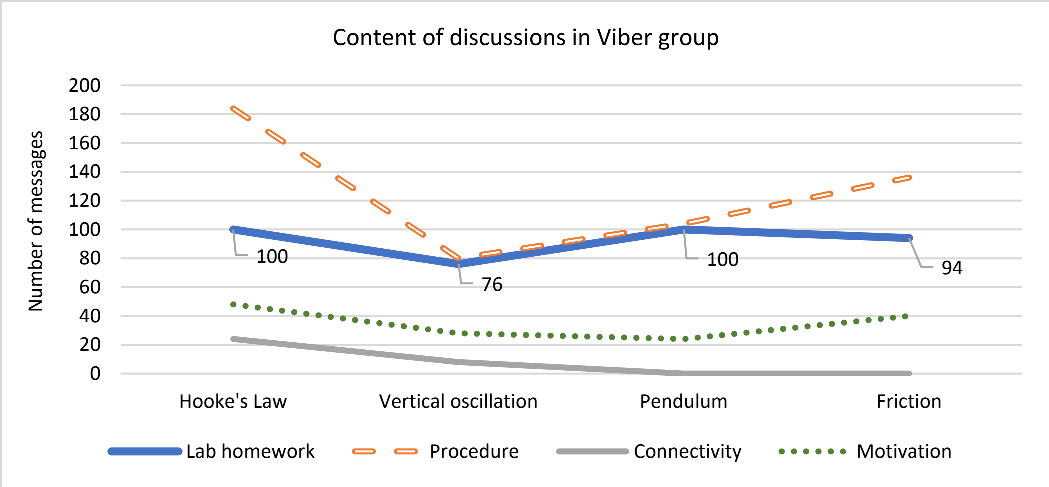

Figure 3. Classification of messages in Viber group

Figure 3 depicts the number of messages per topic for each of the four categories: (a) Procedural issues (b) Lab homework, (c) Connectivity issues, and (d) Discussion for motivation purposes. As can be observed, during the four topics of the Lab sequence, a significant number of messages dealt with issues pertaining to Critical Thinking and Problem-Solving skills. By establishing a Viber group, digital mobile devices were used by students to communicate/argue about methods and scientific practices without regard to space or time limitations. The reflective processes through the possibility of further study of dialogues, but also of the distributed material at any time via their mobile devices, and the students' continuous collaboration in the Viber group may have aided in the development of their Critical Thinking and Problem-Solving skills.

The deep thinking through the study/explanation of the diagrams that MBL created in real time, as well as their storage in the mobile devices of the students for further study and analysis at home, in combination with the reflective processes that inquiry-based learning strategy required (Experiment and Reflective Design Plan sheets) may have contributed to the promotion of students' Critical Thinking & Problem-Solving skills. In addition, the shared session affordance of SPARKvue enabled the involvement of students who were unable to attend some group sessions in person, keeping them involved throughout the whole Lab sequence.

3.2 Students' Perspectives and Assessment of Critical Thinking & Problem-Solving Skills

Six out of ten students agreed with the eight items of the questionnaire regarding Critical Thinking and Problem-Solving before their participation in the mobile-supported Labs, whereas eight of them agreed thereafter. Students' agreement with the items of the questionnaire means their own acknowledgment of the enhancement of Critical Thinking & Problem-Solving skills.

In order to explore in depth the development of Critical Thinking and Problem-Solving skills, students (S1 to S10) were asked open-ended questions before and after the Lab sequence (Appendix B). As shown in Table 1, the responses of the students were categorised and arranged according to four characteristics.

Table 1. Categorizing students' written answers about Critical Thinking & Problem-Solving

	Critical Thinking and Problem-Solving	**PRE**	**POST**
1	Reflecting/monitoring, evaluating processes of thought	**3**	**9**
2	Proposing alternative and viable solutions	**5**	**8**
3	Analysing, synthesizing, and evaluating	**0**	**4**
4	Detecting the Problem	**1**	**2**

As demonstrated in Table 1, three out of ten students reported pausing to reflect during the experiment, suggesting to the critical thinking ability of "reflection and analysis of mental processes." Following the Lab sequence, nine out of ten students reported pausing to analyse and reflect on the process. S1 said, "*Occasionally, I pause to decide if what I'm doing is correct or incorrect*". Additionally, students were asked to define what "alternative options" meant to them. Prior to the Lab sequence, only five out of ten students mentioned alternative viable answers to a Problem. However, following the Lab sequence, eight out of ten students identified alternative viable solutions as a characteristic of Critical Thinking and Problem-Solving skills. Exemplary student responses include: S5 "*For me, alternative solutions involve exploring all potential answers to a Problem while concurrently confirming my results*". Prior to the Lab sequence, no student said that appraisal of a claim or piece of information, analysis of a difficult circumstance, and synthesis are essential factors for finding answers, however, four students did so thereafter. Indicatively, S4 stated, "*I always attempt to consider a suggestion or piece of information that a groupmate provides*", and S8 mentioned that "*each time I attempt to assemble the data I acquire, it is like putting together a puzzle*". One student before the Lab sequence and two students after it acknowledged identifying a Problem as a precondition for proceeding. After the Lab sequence, S8's response to the question "What makes you a competent issue solver?" is "*My ability to utilise past knowledge helps me to tackle the issues I encounter. However, the prerequisite to deal with a Problem, is to identify it*".

4. CONCLUSIONS

The aim of this study was to investigate how Critical Thinking & Problem-Solving Skills are evaluated in a mobile-supported Lab sequence and to what extent the Post-Lab Viber communication contributes. The students' participation in discussions through their smartphones, before and after the Lab experimentation in the class, gave them the opportunity to develop their Critical Thinking & Problem-Solving skills. Specifically, the student's participation in the Viber group, during the pre-phase of the Lab sessions, allowed for reflection on the scenario and the possible ways of controlling their hypotheses. The captured graphs of the experimental data, saved on students' smartphones, were the starting point for each of them to discuss and reflect on the results through the Viber group even outside the Lab class in the school. This fact also ensured the continuous involvement of the students in the reflection both before and after the execution of the experiments.

This study's findings represent a micro-level scenario and can contribute to the expansion of the literature on the subject of mobile learning, which has not been systematically incorporated into the Greece education system's curriculum. This is an ongoing project. Future goals include the investigation of what extent mobile-supported Labs promote other 21st century skills, such as creativity, collaboration, and communication.

REFERENCES

Agustina, N., Mayuni, I., Iskandar, I., & Ratminingsih, N. M. (2022). Mobile learning application: Infusing critical thinking in the EFL classroom. *Studies in English Language and Education, 9*(2), 16. https://doi.org/10.24815/siele.v9i2.23476

Cavus, N., & Uzunboylu, H. (2009). Improving critical thinking skills in mobile learning. *Procedia-Social and Behavioral Sciences, 1*(1), 434-438. https://doi.org/10.1016/j.sbspro.2009.01.078

Fisher, M., & Baird, D. E. (2006). Making mLearning work: utilizing mobile technology for active exploration, collaboration, assessment, and reflection in higher education. *Journal of Educational Technology Systems*, *35*(1), 3-30. https://doi.org/10.2190/4T10-RX04-113N-8858

Halpern, D. F. (1998). *Teaching critical thinking for transfer across domains: Disposition, skills, structure training, and metacognitive monitoring. American Psychologist, 53(4), 449–455.* https://doi.org/10.1037/0003-066x.53.4.449

Hwang, G. J., Lai, C. L., Liang, J. C., Chu, H. C., & Tsai, C. C. (2018). A long-term experiment to investigate the relationships between high school students' perceptions of mobile learning and peer interaction and higher-order thinking tendencies. *Educational Technology Research and Development*, *66*(1), 75-93. https://doi.org/10.1007/s11423-017-9540-3

Ismail, N. S., Harun, J., Salleh, S., & Zakaria, M. A. Z. M. (2016). Supporting students' critical thinking with a mobile learning environment: a meta-analysis. In *10th International Technology, Education and Development Conference. Valence, Spain: INTED2016 Proceedings* (pp. 3746-55). https://doi.org/10.21125/inted.2016.1899

Lai, C. L., & Hwang, G. J. (2014). Effects of mobile learning time on students' conception of collaboration, communication, complex problem–solving, meta–cognitive awareness and creativity. *International Journal of Mobile Learning and Organisation, 8*(3-4), 276-291. https://doi.org/10.1504/IJMLO.2014.067029

McCann, S., & Camp Pendleton, C. A. (2015). Higher order mLearning: Critical thinking in mobile learning. *MODSIM World*, *208*, 1-11.

OECD. (2005). *PISA 2003 Technical Report*. Paris: OECD

Pedaste, M., Mäeots, M., Siiman, L.A., de Jong, T., van Riesen, S.A.N., Kamp, E.T., Manoli, C.C., Zacharia, Z.C., Tsourlidaki, E. (2015). Phases of Inquiry-Based Learning: Definitions and the Inquiry Cycle. *Educational Research Review, 14,* 47–61. https://doi.org/10.1016/j.edurev.2015.02.003

Saputra, M., & Kuswanto, H. (2019). The Effectiveness of Physics Mobile Learning (PML) with HomboBatu Theme to Improve the Ability of Diagram Representation and Critical Thinking of Senior High School Students. *International Journal of Instruction*, *12*(2), 471-490. https://doi.org/10.29333/iji.2019.12230a

Sharples, M., Arnedillo-Sánchez, I., Milrad, M., & Vavoula, G. (2009). Mobile learning. In: Balacheff, N., Ludvigsen, S., de Jong, T., Lazonder, A., Barnes, S. (eds). *Technology-enhanced learning* (pp. 233-249). Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9827-7_14

SPARKvue (4.7.1.8). (2014). [Mobile app]. PASCO.

Stephenson, N. S., Miller, I. R., & Sadler-Mcknight, N. P. (2019). Impact of peer-led team learning and the science writing and workshop template on the critical thinking skills of first-year chemistry students. Journal of Chemical Education, 96(5), 841–849. https://doi.org/10.1021/acs.jchemed.8b00836

Unlu, Z. K., & Dokme, I. (2017). Science teacher candidates' epistemological beliefs and critical thinking disposition. *Eurasian Journal of Educational Research, 72,* 203-220. https://dergipark.org.tr/en/pub/ejer/issue/42492/511913

Wyatt, S. (2005). Extending inquiry-based learning to include original experimentation. *The Journal of General Education*, *54*(2), 83-89. https://www.jstor.org/stable/27798010

Zacharia, Z. (2003). Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *40*(8), 792-823. https://doi.org/10.1002/tea.10112

Zheng, L., Chen, N. S., Li, X., & Huang, R. (2016). The impact of a two-round, mobile peer assessment on learning achievements, critical thinking skills, and meta-cognitive awareness. *International Journal of Mobile Learning and Organisation,* 10(4), 292-306. https://doi.org/10.1504/IJMLO.2016.079503

APPENDIX A: QUESTIONNAIRE

Critical Thinking & Problem-Solving

- I ask myself periodically if I am meeting my goals.
- I consider several alternatives to a Problem before I answer.
- I find myself pausing regularly to check my comprehension.
- I ask myself questions about how well I am doing once I finish a task.
- When facing Problems, I believe I have the ability to solve them.
- I believe I can put effort into Solving Problems.
- I can solve Problems that I have met before.
- I am willing to face Problems and make an effort to solve them.

APPENDIX B: OPEN-ENDED QUESTIONS

- Do you consider it essential to make pauses and think-over, when you work in Lab or for homework? Please explain.
- What is the meaning of “alternative solutions” to you?
- What makes you a “strong Problem solver”?