Teacher Perceptions of Incorporating Engineering Design in Mathematics and Science Instruction (Research)

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Middle School STEM Teachers' Understandings of Computational Thinking: A Case Study of Brazil and the USA

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Middle School STEM Teachers' Understandings of Computational Thinking: A Case Study of Brazil and USA

Abstract

In recent years, computational thinking has received increasing amounts of attention, with numerous K-12 institutions looking to incorporate it into existing STEM curriculums. This movement to improve computational thinking literacy, supported by numerous professional organizations (e.g., American Society for Engineering Education [ASEE], National Research Council [NRC], National Academy of Engineering [NAE]) and Next Generation Science Standard (NGSS Lead States, 2013), attempts to improve students' problem-solving skills and strategies. Efforts to improve computational thinking have been aimed at both teachers and students. However, few studies exist to investigate how teachers implement the teaching of CT practices in courses with a component that involves collaboration between students in multiple countries. Therefore, the focus of the study is to explore middle school STEM teachers' understandings of computational thinking practices, if any, within an integrated STEM education teaching approach. This study is an international study, as the teachers are from two countries, Brazil and the United States. For this study, an extensive semi-structured interview protocol is used to gather data from a sample of four middle school STEM teachers. All of the teachers are communicated with in English to collect the data. A case study method is implemented to collect and analyze interview data to identify similarities across cases. Member checking is used to confirm accuracy in the results. Findings from this study offer insights for researchers, middle school teachers, curriculum developers and professional development providers.

Introduction

From a global perspective, STEM education has developed semi-independently in order to meet different needs amongst different populations. In order to meet local standards and needs, numerous countries have explored various teaching strategies for math and science topics in K-12 education, in order to expand student learning opportunities (Jorde & Dillon, 2012). For example, in France, Israel, and the Netherlands, educators have combined the content of science and technology subjects (Moon, Brown, & Ben-Peretz, 2000). Other countries (e.g., Canada, United States, Sweden) have a different approach in integrating various STEM subjects within school setting, such as implementing instruction on engineering design processes and practices in science and/or technology education curriculum (e.g., NGSS Lead States, 2013). Other nations have developed engineering programs for their schools by combining science, mathematics, and technology subjects (Ritz & Fan, 2015). While all of these countries have demonstrated a similar commitment to STEM education, each has differing national priorities for an education system; therefore, the outcomes have been likewise different.

Furthermore, Ritz and Fan (2015) suggested that there are many reasons why STEM education is vital across cultures, specifically within K-12 school curriculum. According to them, one justification for expanded STEM learning would be to increase students' interests and motivations towards STEM fields. Another reason would be to increase the number of students whose concentration is on STEM and transfer the knowledge into the workforce, particularly in nations where STEM-related careers are in demand. As there are a number of potential motivations for the introduction or advancement of STEM curriculums, the intentions backing individual nations' reforms may vary highly from country to country. Therefore, reforms in STEM education may become a critical topic to discuss further around the world (Ritz & Fan, 2015).

It is important for pre-college students to be exposed to STEM subjects to maintain and increase their motivation towards a particular STEM field where they can advance their knowledge and critical thinking skills (English, 2016). Such efforts have been made to incorporate both engineering and CT in existing STEM curriculum. Furthermore, a new emergence of computational thinking competencies and practices has been recently expanded through a federally funded project within STEM+C program that emanates the idea of exploring CT and integrated STEM education through a curriculum based dedicated for 5-8 year old and science center exhibit (e.g., Hynes et al., 2019).

Computational Thinking

Computational thinking (CT) competencies and practices have been receiving a great deal of attention from several groups of professionals, notably including educational researchers, practitioners, educators, curriculum developers, and professional development providers. This movement, supported by numerous professional organizations (e.g., American Society for Engineering Education [ASEE], National Research Council [NRC], National Academy of Engineering [NAE]) and Next Generation Science Standard (NGSS Lead States, 2013), is focused on improving students' problem-solving skills and strategies. Many of these efforts have been aimed at improving the CT educational process, both from a teaching and from a learning perspective.

Although the term CT has deeper roots than those planted by Papert's (1980) *Mindstorms: Children, Computers, and Powerful Ideas*, the term has increasingly found its way into research and K-12 STEM education. Consequently, the field of CT has been an attractive concept and has inspired educational researchers to investigate the most effective ways to foster such competencies and practices in K-12 school settings (e.g., Dandridge et al., 2019). CT has been defined in various ways. For example, according to Wing (2006), CT "represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use" (p. 33). Furthermore, Wing clarified that CT is required for solving problems, designing a set of structure, and interpreting behavioral interactions. Moreover, according to Lee et al. (2011), CT shares the “elements with various other types of thinking such as algorithmic thinking, engineering thinking, and mathematical thinking” (p. 32).

Figure 1. A cognitive framework on the essence of CT skills [Adapted from Yasar, 2018, p. 37]

Additionally, recent studies (e.g., Wing, 2006; Yasar 2018; Yasar et al., 2016) suggest that teachers need to introduce CT not only in higher education but also in pre-college settings due to interdisciplinary applications such as STEM and literacy. Denning and Freeman (2009) showed that, although the approach to developing CT skills may be distinctive, this approach can be applied across STEM disciplines. Furthermore, Wing (2006) suggested that CT complements, and is rooted within, mathematics and engineering thinking. CT practices are also appropriate to incorporate into existing K-12 curriculum, which could improve students’ learning. For example, recent studies (e.g., Ehsan, Dandridge, Yeter, & Cardella, 2018; Hynes et al., 2019) suggest that early elementary students are able to demonstrate CT competencies in their classroom activities. Moreover, additional recent studies (Diordieva, Yeter, & Smith, 2018; Yasar et al., 2016) suggest that CT has critical components that can be incorporated appropriately within more general STEM topics.

CT has been shown to have a positive impact on improving teachers’ instructional practices (e.g., Yadav, Gretter, Good, & McLean, 2017; Yasar et al., 2016) that may potentially improve students’ outcomes which is a critical component for improving educational settings (e.g., Diordieva et al., 2018). Connectively, teachers are one of those important factors that influence students’ learning outcomes. Although there has been an emphasis on CT implementation within K-12 settings through professional development for in-service teachers, very few investigations have been conducted on teachers' perceptions of practices of incorporating CT into their actual classroom instruction. Therefore, this study’s intention was to explore middle school STEM teachers' perceptions of CT practices.

Purpose of the Paper

The purpose of conducting this study was two-fold. First, the study was an exploration of the perceptions of middle school STEM teachers' computational thinking practices within an integrated STEM education teaching approach. Second, the study focused on the observed computational thinking practices of international middle school STEM teachers. This was an international study and the participants (i.e., teachers) are from the countries of Brazil and the United States.

Research Questions

Two overarching research questions that will be addressed within this study are:

1. How do middle school STEM teachers from Brazil and the United States perceive and characterize computational thinking practices?
2. What are the similarities and differences, if any, in the experiences expressed by middle school STEM teachers from two countries while implementing computational thinking practices in an integrated STEM activity?

Project Description

The World MOON Project, a program developed around student observations of the aerospace topics (e.g., moon and its phases), has an interdisciplinary approach that aims to generate a new perspective in teaching an integrated STEM modeling with an inquiry- and problem-based learning. Studies from the project provide empirical evidences that 1958 early adolescent students (1029 females and 929 males) those who participated in the project had a significant improvement in their aero-science related topics (e.g., Yetter, Livengood, & Smith, 2017). The project is based on the collaboration which promotes national and international STEM education and provides 21st century skills to dozen of teachers and hundreds of students (e.g., Trundle, Willmore, & Smith, 2006; Yeter & Koca, 2013). The project illuminates CT competencies (e.g., pattern recognition, data collection, data analysis, simulations) that potentially may empower STEM teachers' instructional practices and improve their students' understanding of CT.

In addition, though the project includes students from the United States, its scope is international and numerous nationalities are represented. Students around the globe are required to observe the moon and by identifying patterns, as one of the CT competencies, to gain a deeper understanding of an integrated STEM modeling through observing the nature. Students write an essay about their daily observations and exchange with their peers anonymously from different countries in opposite (northern and southern) hemispheres. That way students receive essays from other international students that provide both a local and global perspectives.

The Project Participants

Teachers and students from different countries participate in the project every semester. The fall semester usually starts from August to November, and the spring semester from January to April. All teachers can enroll their students for free. The handbooks are available online and written for grades 4-8, but the project is for all ages, through K-16. The project is mainly in English, but also available in Chinese, Arabic, Spanish, French and Portuguese languages.

The Project Timeline.

The project has four phases, and they are described as follows.

Phase 1- Observations (6 weeks)

Students watch the moon almost every day for six weeks. The observations take up one lunar cycle and from the next lunar cycle a waxing portion so that students have a clear understanding from their local view of the moon shape. The learning process is guided by their teacher, so the teacher takes up the control over what students learn about each moon phase.

Phase 2- Observation Essays and Analysis (3 weeks)

After their observations and note-taking, students start writing a short essay on the three specific dates given by the project. The specific dates usually match with a waxing crescent, first quarter or waxing gibbous moon. After that, these essays are uploaded by students to the project website. After uploading the essays, the project creates groups and combines approximately ten essays per group from students from different countries. The students receive their local essays and the other locations' essays. The guidelines supported in the *Teacher Handbook* and *Student Handbook* describe the global patterns that students should look for and write in their essays. For example, students should recognize the orientation of the moon based on the same lunar phase and day from different locations.

Phase 3- Global Patterns Essays and Analysis (3 weeks)

Students write and upload their essays about the global moon patterns they discovered. The essays are again distributed into groups of approximately ten essays from different locations and sent out to the students.

Phase 4- Causal Explanation Essays and Analysis (3 weeks)

The third essay written by the student reflects student's selection and causal explanation of a pattern in a brief essay. After that, the essays are being divided in groups of ten and distributed to students.

Comprehensive Moon Phases Assessment - Revised (CMPA-R)

The Comprehensive Moon Phases Assessment - Revised (CMPA-R) post assessment includes 31 questions with a multiple-choice format, available free for students in the project. It is an online assessment that takes up around 30 minutes to be completed. It can be taken optionally, but it is suggested for teachers to take both pre- and post-test. Also, students are advised to take the pretest so that teachers can see their weak areas and progress their growth. After observations teachers obtain a report of the pre-test results. Five subsections are included in the assessment to test students' knowledge on:

1. Observations on moon phases and related vocabulary.
2. Causes of moon phases and eclipses.
3. Moon phases from a global view.
4. Moon motion.
5. Sizes and distances between Earth-Moon-Sun.

Method

Research Design

A case study approach (e.g., Yin, 2009) was taken in order to explore international middle school STEM teachers' understandings of computational thinking practices within an integrated STEM education teaching approach. To identify the actual meaning of the terminology used by instructors regarding computational practices, the qualitative design method was implemented to code, analyze, and record the findings (Merriam, 1998). For the internal validity the researchers used the findings of the common themes amongst the cases (Yin, 2009) and member checking was effectuated to ensure the credibility, accuracy of the data collection, and analysis (Harper & Cole, 2012). The member checking process is useful in qualitative research since it helps to confirm and obtain the results by checking with the participants and excluding the potential bias (Birt et al., 2016). Finally, a case study was a suitable approach to use to individualize each case. Through a descriptive approach to each case, a qualitative method helped the researchers construct and analyze each case and identify the replications among the cases. The analogies, differences, and replications assured the external validity of the data throughout the exploration of the cases (Baxter & Jack, 2008).

Study Participants

Teachers' backgrounds played an important role in answering the research study questions. Therefore, the purposive sampling method was used for the study (Patton, 2012). The participants were four middle school STEM teachers from two countries. One was from Brazil, and three were from the United States. Selection of participants was based on their teaching experience in at least one of the STEM subjects. Teachers' years of teaching experience varied from 5 years to 20 years. The interview was carried out in English. Table 1 provides detailed demographic information about the participants. A sample of the interview protocol is provided in Appendix A.

Table 1. Participants' Demographic Information

Teacher's Name (Pseudonyms)	Country	Gender	Teaching Subject
Mira	Brasil	Female	Mathematics, Science, Literacy
Danyel	Pennsylvania, USA	Male	Science/STEM
Laura	California, USA	Female	Science, Library
Kate	Missouri, USA	Female	Science/STEM

Data Collection and Procedures

The data were collected through interviews. The interview protocol was developed in consultations with subject matter and experts in the field of computational thinking practices. Moreover, upon approval of the Institutional Review Board, the participants were contacted to schedule an interview. All interviews took approximately 45 minutes. Each participant was asked to respond to similar questions to assure that the information provided would be sufficient to answer the research questions (Kvale, 2008) A semi structured interview encouraged teachers to convey their experiences, ideas, and attitudes (Yin, 2009). All teachers were interviewed in English. Upon agreement of the participants, the interviews were audio-recorded, transcribed, and analyzed. For further clarification, a follow-up email was sent to request more information. Anonymized identifications were used to maintain the confidentiality of the participants' identities.

Data Analysis and Member Checking

The researchers listened to each interview and transcribed each into an MS Word document. Transcription helps to accurately identify common codes, and subsequently, major themes between the cases (Burnard, 1991). The transcriptions were coded and analyzed by the researchers to discover common themes and obtain cross-case conclusions. The researchers coded data individually. Afterward, the researchers discussed the possible meanings of the themes and came to agreement on all themes developed. Member checking was used to confirm the accuracy of the results and the themes developed between the researchers (Merriam, 1998). The triangulation, in terms of data and researchers, was carried out to obtain more validity. By checking the data and the collection process, this method allows the researchers to obtain validity and assurance from interpretations and conclusions taken from participants who took part in the qualitative interview (Goldblatt, Karnieli-Miller, & Neumann, 2011). Further analysis conducted by the researchers helped to identify the commonalities between the cases. Several themes emerged from readings and coding of the data.

Findings

Based on the analysis from four teachers (three from the USA and one from Brazil), findings show that all teachers have agreed that while CT provides potential opportunities and benefits to the classroom, it can also bring some challenges to school setting. Further evidences pertaining to first research question showed that all participants perceived CT as problem solving strategies, coding programs, and technology tools. In addition, one of the participants specifically expressed that CT is not only tied to a specific discipline (e.g., mathematics, computer science), it fits to other non-STEM subjects, for instance, literacy, history, music, and economics. This evidently indicates that the teacher had a clear understanding of CT that has interdisciplinary components across multiple disciplines. All four participants stated that *data collection, data analysis, pattern recognition,* and *simulations* CT competencies were the most useful practices that were exhibited by their students while they were engaged in the project. For example, study participant and teacher Danyel stated that his students go through all of these competencies while he taught inquiry process learning strategies during the project. More specifically, he stated CT included:

> "Design activities for [my] students that will incorporate them like data collection, data analysis, [and] data representation. ...through exploration and investigation of analysis, being able to engage in [the project]."

Among all teachers, Danyel was the only teacher who stated that his students should have been exposed to CT as early age as possible to acquire CT competencies. Specifically, he stated that "the idea of CT is important, the earlier you can teach children to think logically... put things in a logical order… the sooner they can engage in a complex computing or programming than the otherwise."

In term of the second research question, all teachers believed that CT practices had influenced their students to think more critically while they were engaged in the project. For example, one of the teachers, Mira, specifically indicated that her students started to improve their "faster thinking" and "multi-tasking" abilities. Yet, she provided a couple of examples of how CT thinking facilitated her students to face with issues when it comes to a design challenge by practicing simulation competency. She related that such challenges could be an opportunity that could improve her students' CT competencies in their daily life activities. She stated "the opportunity of doing and redoing, going and coming back… when it can simulate something and see if it gets there … because next time they face a new challenge."

Meanwhile, Laura gave examples of how CT practices within the project helps her students to improve their CT competencies and allow them to learn independently and gain a deeper knowledge about a specific content. She stated CT practices "help them [her students] to question things [critically]... to go deeper into a subject."

Moreover, all of the teachers expressed that their students improved their understanding of CT competencies including *data collection, data analysis, pattern recognition,* and *simulations* throughout the project. However, among those CT competencies, understanding of *pattern recognition* was competency students developed the most improvement in while engaged in the project. For instance, Mira expressed that "I would say it is the soul of the project… because of the patterns, they notice that something is different, so when they have to explain [lunar phases in both southern and northern hemispheres], they have to solve based on these patterns." Another teacher, Danyel, indicated that the pattern recognition students demonstrate throughout the project engages students in practicing CT competency. He stated that "when they start analyzing their [lunar] data and the rest of the data from students around the world [in different hemisphere], they are looking for patterns of similarity and differences that is explicit in the instructions in the MOON Project... It [the project] tells them look for patterns."

Discussion

The overall findings about similarities and differences of computational thinking practices and perceptions (as perceived by middle school STEM teachers in the two nations noted) through an integrated STEM activity were analyzed and studied for research implications. Nevertheless, it is critical to conduct extensive further qualitative research since there exists limited research addressing international middle school teachers' perspective on computational thinking practices in STEM fields.

The primary finding showed that all participants perceived CT as problem solving strategies (e.g., analytical thinking skills, creating a timeline), coding program (e.g., Kodable, Scratch), and technology tools (e.g., iPads, internet, cell phones). More importantly, the participants acknowledged the fact that CT is related not only to traditional STEM disciplines, but also to non-STEM subjects. From this point of view, the implementation of CT can be viewed as a tool bridging multiple disciplines. Results from other recent studies also concur that CT practices have been perceived by pre- and in-service teachers as an interdisciplinary connection across different subjects (e.g., Rehmat, Ehsan, Yeter, Moore, & Cardella, 2019; Yadav, Mayfield, Zhou, Hambrusch, & Kor, 2014).

Moreover, CT practices and its implementation creates a more secure and independent learning environment. As student learns how to solve problems independently, it has been observed to build their sense of confidence in the learning process. Acquiring CT competencies and practices is important, particularly at an early age. Further studies suggest that first grade students were able to exhibit CT competencies while engaged in integrated STEM activities (Ehsan et al., 2018).

One of the competencies recognized and discussed by all teachers in the study was CT-related pattern recognition. All four teachers emphasized that pattern recognition CT competency improved their students' critical and analytical thinking skills as well as problem solving strategies. Lastly, findings through this study suggest that implementing CT practices not only helped students, but also teachers to think more critically and improve understanding of CT practices.

Limitations of the Study

Few limitations were found that may affect this qualitative study. The study includes relatively small geographical range of participants, and as a consequence, the findings may not be generalized to the whole population of middle school teachers to obtain a better data validation. Interviews were the only data collection source and so the answers from the teachers are assumed to be honest. Additionally, data analysis was based solely on interviews, which is why teachers' perceptions might not sound persuasive enough to defend their claims.

Conclusion, Implications and Future Recommendations

This study intends to provide middle school STEM teachers' perception about computational thinking within an integrated STEM project. As a limited number of studies exist to investigate teachers' understanding of CT from various countries, this study provides a significant contribution in the field of computational thinking in STEM education, teacher education and global studies. Consequently, findings from this study are intended to offer insights for researchers, middle school in-service STEM teachers, STEM curriculum developers and professional development providers, teacher educators, and practitioners. The focus of the study is to explore each teachers' perception in greater depth. However, the case study method cannot be generalized to all cases. Furthermore, the study explores only CT implementation, and the claims made are based on short-term observations as opposed to long term perceptions. The interviews provide a broader picture of overall middle school STEM teachers' perceptions and implementation of CT practices from both Brazil and USA; however, the interviews were not focused on the specific subject of studying the CT practices, but rather on general observations of STEM education that teachers made while their students were engaged in the project.

In order to increase CT practices in different subjects, there is a need of support in teacher education in this regard. For instance, Chang and Peterson (2018) developed an educational technology course for pre-service teachers by introducing CT concepts in relation to technology. Further, findings from this study provide rigorous evidence for teacher educators to incorporate CT practices in their current pre-service teacher education programs and in-service teachers' professional developments. Such findings may also help curriculum developers to design CT-integrated curricula regardless of relation to STEM given the observed interdisciplinary nature of CT competency.

Future studies should explore further investigations on CT field. For example, there are multiple stereotypes and attitudes concerning CT practices that relate to the learning progress (Mercier, Barron, & O'Connor, 2006). It is also crucial to identify how learning experiences can be improved by including CT practices. In order to gain a broader picture of teachers' perspective on CT definition much of the theoretical and practical understanding should be explored.

References

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report*, *13*(4), 544-559.

Birt, L., Scott, S., Cavers, D., Campbell, C., & Walter, F. (2016). Member checking: A tool to enhance trustworthiness or merely a nod to validation? *Qualitative Health Research, 26*(13), 1802-1811.

Burnard, P. (1991). A method of analyzing interview transcripts in qualitative research. *Nurse Education Today*, *11*(6), 461-466.

Chang, Y.h. & Peterson, L. (2018). Pre-service teachers' perceptions of computational thinking. *Journal of Technology and Teacher Education, 26*(3), 353-374.

Dandridge, T. M., Ehsan. H., Gajdzik, E., Lowe, T., Ohland, C., Lowe, T., Yeter, I. H., Brophy, S. & Cardella, M. (2019, February). Integrated STEM+ C learning for K-2 aged children: CT competencies as a precursor to K-2 computer science education. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (pp. 1280-1280). ACM.

Denning, P., & Freeman, P. (2009). Computing's paradigm. *Communications of the ACM, 52*(12), 28–30.

Diordieva, C., Yeter, I. H., & Smith, W. (2018, June). Cross-case analysis: K-12 international teachers' perspectives on integrated STEM and computational thinking practices. In *Proceedings of the American Society for Engineering Education (ASEE) Conference & Exposition,* Salt Lake City, UT.

Ehsan, H., Dandridge, T. M., Yeter, I. H., & Cardella, M. E. (2018, June). K-2 students' computational thinking engagement in formal and informal learning settings: A case study (Fundamental). In *2018 ASEE Annual Conference & Exposition*, Salt Lake City, UT.

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education, 3*(1), 3.

Goldblatt, H., Karnieli-Miller, O., & Neumann, M. (2011). Sharing qualitative research findings with participants: Study experiences of methodological and ethical dilemmas. *Patient Education and Counseling, 82*, 389–395.

Harper, M., & Cole, P. (2012). Member checking: can benefits be gained similar to group therapy? *The Qualitative Report*, *17*(2), 510-517.

Hynes, M., Cardella, M., Moore, T., Brophy, S., Purzer, S., Tank, K., Menekse, M., Yeter, I.H., & Ehsan, H. (2019). Inspiring young children to engage in computational thinking in and out of school. In *Proceeding of American Society for Engineering Education (ASEE) Conference & Exposition.* Tampa, FL.

Jorde, D., & Dillon, J. (2012). Science education research and practice in Europe. In D. Jorde & J. Dillon (Eds.), *Science education research and practice in Europe*, (5), 1–11. Rotterdam: Sense Publishers.

Kvale, S. (2008). *Doing interviews.* Thousand Oaks, CA: Sage Publications.

Lee, I., Martin, F., Denner, J., Coulter, B., Allan, W., Erickson, J., Malyn-Smith, J., & Werner, L. (2011). Computational thinking for youth in practice. *ACM Inroads, 2*(1), 32-37.

Mercier, E. M., Barron, B., & O'Connor, K. M. (2006). Images of self and others as computer users: The role of gender and experience. *Journal of Computer Assisted Learning, 22*(5), 335–348.

Merriam, S. B. (1998). *Qualitative research and case study applications in education.* San Francisco, CA: Jossey-Bass.

Moon, B., Brown, S., & Ben-Peretz, M. (Eds.). (2000). *Routledge international companion to education.* London: Taylor and Francis Books

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc.

Patton, M. Q. (2002). Qualitative interviewing. *Qualitative Research and Evaluation Methods*, *3*, 344-347.

Rehmat, A. P., Ehsan, H., Yeter, I., Moore, T., & Cardella, M. (2019). *Exploring elementary teachers and students' perceptions of computational thinking school and imagination station*. National Association for Research in Science Teaching (NARST) Conference, Baltimore, MD.

Ritz, J. M., & Fan, S. C. (2015). STEM and technology education: International state-of-the-art. *International Journal of Technology and Design Education*, *25*(4), 429-451.
Trundle, K., Willmore, S., & Smith, W. (2006). The MOON project. *Science and Children, 43*(6), 52-55.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33-35.

Yadav, A., Gretter, S., Good, J., & McLean, T. (2017). Computational thinking in teacher education. In *Emerging Research, Practice, and Policy on Computational Thinking* (pp. 205-220). Springer, Cham.

Yadav, A., Mayfield, C., Zhou, N., Hambrusch, S., & Korb, J. T. (2014). Computational thinking in elementary and secondary teacher education. *ACM Transactions on Computing Education (TOCE), 14* (1), 5.

Yasar, O. (2018). A new perspective on computational thinking. *Communications of the ACM 61*(7), 33-39.

Yasar, O., Veronesi, P., Maliekal, J., Little, L., Vattana, S., Yeter, I. (2016). Computational pedagogy: Fostering a new method of teaching. *Computers in Education Journal, 7*(3), 51-72.

Yeter, I. H., & Koca, F. (2013, March). 21st century skills and international STEM education collaboration. In *Society for Information Technology & Teacher Education International Conference*. Association for the Advancement of Computing in Education (AACE), New Orleans, LA.

Yetter, I. H., Livengood, K. K., & Smith, W. S. (2017). State science standards and students' knowledge of what states value: Lunar phases. *Electronic Journal of Science Education, 21*(1), 36-55.

Yin, R. K. (2009). *Case study research: Design and methods (4th ed.).* Thousand Oaks, CA: Sage Publications.

Appendix A
Sample Interview Questions & Protocol

Demographic Questions:

1. What grade level do you teach?
    a. For how long have you been teaching?
2. What is your educational background?
3. Have you ever taught any other subjects? If yes, what subjects?

General Questions:

4. What do you know about computational thinking (CT)?
    a. What are the skills/competencies make a CT?
    b. Any examples?
5. What is the value being involved in the WMP project?
    a. Do you see any CT competencies in the project? Please explain.
6. Do you see any CT competencies in other subjects (e.g., Science, Math, and Literacy)? Please explain.
7. Do you see a value in students learning CT competencies? Why?

Closing Questions:

8. What CT competencies that you think your students learned the most from the project?
9. What would you like to add?
10. Do you have any questions?