Hands-on, Minds-on, Hearts-on, Social-on: A Collaborative Maker Project Integrating Arts in a Synchronous Online Environment for Teachers

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Accepted: 13 April 2022 / Published online: 2 May 2022 © Association for Educational Communications & Technology 2022

Abstract
This article presents a collaborative maker project integrating the arts in a synchronous online environment. Based on the Thinkering, Making, Sharing, and Reflecting (TMSR) model, the four components of hands-on, minds-on, hearts-on, and social-on learning were integrated into an online collaborative maker project involving arts, music, and coding. The authors first describe the theoretical framework of the TMSR model and the design and implementation of the maker project, and then report on the experiences and reflections of the participating teachers, who were enrolled in an online graduate course. Survey results showed that the project fostered the teachers’ connectedness, positive emotions, and satisfaction toward the online learning environment. In addition, qualitative data from their reflective essays revealed that the teacher participants experienced all aspects of hands-on, social-on, hearts-on, and minds-on learning in the online environment both as learners and as teachers. Finally, the qualitative themes showed that the teachers acknowledged supportive maker project components that can be applied in their own teaching context. Implications of the findings for art-integrated maker projects in public school settings were also addressed.

Keywords Arts integration · Coding · Collaboration · Constructionism · Inservice teachers · Maker project · Online learning · STEAM · Under-resourced schools · Virtual orchestra

Online higher education courses provide students with ease of access to content, flexible scheduling, and the convenience of being able to log in from any location. Despite these advantages, several challenges have been documented in online learning communities, primarily related to limited communication and interactions between students and instructors and among the students themselves, often leading to feelings of isolation and disconnectedness (Angelino et al., 2007; Bolliger & Inan, 2012) and resulting in higher student dropout rates (Mubarak et al., 2020).

A plethora of research has highlighted the importance of providing socially, emotionally, and academically integrated learning experiences to ensure students’ satisfaction with and persistence in completing online courses (Kanuka & Jugdev, 2006). In particular, the perception of psychological presence, relationships with cohorts, opportunities to connect with peers and instructors and, more important, meaningful construction of knowledge through collaborative activities are described as significant predictors of successful online learning (Angelino et al., 2007; Bolliger & Inan, 2012; Rovai, 2002; Shin, 2003; Tu, 2002).

Hence, numerous studies have investigated student engagement, interactions with content and peers, integration of student-centered teaching approaches, and effective group learning in online environments (An et al., 2009; Hara, 2000; Lee & Martin, 2017). However, most of these studies have focused on asynchronous teaching strategies, such as the use of discussion boards or collaborative projects, that can be completed in isolation. Thus, the creation of synchronous hands-on or collaborative maker projects in online learning...
environments has not received considerable attention in higher education settings.

As noted in the literature, to create a supportive online environment, learning activities should include authentic tasks that are characterized by high levels of social presence and collaboration, as well as projects involving shared goals and values (Cullen et al., 2013; Holmes, 2013). The importance of these elements is not new or unique to online education but has been discussed in face-to-face education, especially in the form the maker movement, which emphasizes learning by making from the perspective of constructionism (Blikstein, 2013; Papert, 1993). As such, the maker movement utilizes physical and digital tools for making and features the collective mindset of playful and collaborative activities (Martin, 2015). These critical features create rich learning opportunities that have the potential to promote authentic and collaborative learning with a higher social presence that shares goals and values, thus addressing the challenges often associated with online education. “Making” means building, creating, or fabricating to produce an artifact (Schon et al., 2014) and, therefore, is closely associated with technologies, artistic tools, and crafting activities.

The maker project in the current study involved the use of technological applications and the arts together. The goal was to examine if implementing the maker project in an online teacher education course that involved doing (hands-on), knowledge and skill-building (minds-on), positive attitudes (hearts-on), and collaborations (social-on) supported participants’ positive experiences with online learning and engagement in learning processes. Specifically, as action research (Suskie, 2018), with the main purpose to inform one’s own practice rather than making broad generalizations, this study presents a collaborative online maker project that built a “masterpiece mosaic” orchestra with peers in a synchronous online environment as an evidence-based practice to inform teachers of effective ways to implement maker tools and teaching approaches in their own classrooms.

**Theoretical Framework**

The study used the theoretical lens of constructionism (Papert, 1993), which builds on the constructivist theories of Jean Piaget (Harel & Papert, 1991). Constructionism supports a constructivist approach, whereby learners act as agents of their own learning and build knowledge, as opposed to knowledge simply being supplied by the teacher. Thus, it highlights the “idea that happens especially felicitously when the learner is engaged in the construction of something external or at least sharable” (Papert, 1991, p. 3). Finally, constructionism is the conceptual foundation for maker projects, which provide hands-on experiences (Papert, 1980; Valente & Blikstein, 2019).

To design effective maker projects, Kang and Kim (2017) developed and employed the Tinkering, Making, Sharing, and Improving (TMSI) model, which adds sharing to the original Thinking, Making, Improving (TMI) model (Hatch, 2013). As delineated in Fig. 1, the current study adopted both models and expanded them into the so-called TMSR model, consisting of Thinkering, Making, Sharing, and Reflecting.

In the TMSR model, “T” stands for “thinkering,” thinking through tinkering, which emphasizes understanding concepts in one’s mind while tinkering with one’s hands (Michalko, 2011). Thinkering, as employed in this study, was not limited to physical construction, but also involved interacting with tools to develop intuitions of how the tools operate (Lim et al., 2015) and strategies for ideation. Improving, the last component of the TMSI model, is replaced with Reflecting in our model because constructionism highlights the importance of sharing and reflection on the artifacts; this is exemplified in the orchestra coding project for this study.

The design of the maker activities within the TMSR model features the four critical aspects of the maker movement (Martin, 2015): (a) the use of digital tools and physical materials for making; (b) community infrastructure such as online resources, physical spaces, and events that support community engagement; (c) playful, asset- and growth-oriented and failure-positive values; and (d) sharing and collaboration. The study operationally defined and developed four essential learning components as conceptualized in Fig. 2: (a) doing and making (hands-on), (b) utilizing resources and building thinking skills (minds-on), (c) playful and positive mindset (hearts-on), and (d) sharing and collaboration (social-on).

Hands-on learning – the heart of the maker movement – involves doing, making, and building an object of interest.
Fig. 2 Application of the TMSR model
The sharing and reflection processes promote collaborative experiences that emphasize “social-on” learning. Kang and Yoon (2017) coined the term social-on to highlight the scaffolds that learners receive from their peers along with instructor interaction. Additionally, the current study highlights the importance of positive values, beliefs, and a failure-positive and growth- and asset-oriented mindset (Martin, 2015) in the “hearts-on” and “minds-on” aspects of maker projects.

In sum, the current study design follows the TMSR framework to achieve (a) “hands-on” doing, (b) “minds-on” learning, (c) “hearts-on” mindset, and (d) “social-on” collaborative learning. These 4-on elements foster motivation and interest through the construction of personally meaningful projects using diverse tools, tinkering with materials, and collaborating with peers. Throughout the TMSR processes, learners are involved in a multitude of scaffolding strategies, including guided learning, constrained activities, open-ended tasks, and collaboration opportunities for individual work, small-group work, and whole-group activities.

**Literature Review**

**Maker Projects**

The maker movement is grounded in constructionism as a means of promoting student-centered learning opportunities that are authentic and personally meaningful for students (Willis & Tucker, 2001). To date, this approach has largely been implemented through the use of technology tools (Han & Bhattacharya, 2001; Valente & Blikstein, 2019). By using tangible and virtual robotics and programming as well as other making technologies, such as Makey Makey (https://makeymakey.com), maker projects bring constructionist theory into reality (Beynon, 2016), creating authentic and collaborative environments, while also supporting learners to develop coding skills and computational thinking (Hsu et al., 2018; Iwata et al., 2020).

Programming education has advanced in the last decade and expanded into K-12 education to support more diverse learning opportunities (Kafai & Burke, 2013). Kafai and Burke (2013) specified three shifts in the field of K-12 programming education as follows: (a) from code to applications, emphasizing the instructional software design approach; (b) from programming tools to communities, emphasizing a collaborative activity; that is, providing a social context in which programming tools are used and programming artifacts are shared; and (c) from scratch to remix, which is a particular form of participation within the Scratch (virtual coding program) community. Such a shift is geared toward better learning opportunities and better teaching opportunities since it allows learners to develop wider cultural perceptions and practices.

Spurred by the potential positive learning outcomes of maker projects, the maker movement, initially started in informal learning environments, has begun to move into more formal school settings (Lindberg et al., 2020). For example, some K-12 schools include maker projects into parts of their curricula, while creating makerspaces in their buildings.

Maker activities allow children to learn through playing, exploring, experimenting, creating, and problem-solving with technology and enable them to apply knowledge to undertake a design process resulting in the creation of artifacts for STEAM (Science, Technology, Engineering, Arts, and Mathematics) (Blackley & Howell, 2015). That is, in addition to STEM (Science, Technology, Engineering, and Mathematics) subjects, many other subject areas can be incorporated into maker activities in an engaging way. For example, young children become more motivated to participate in creative writing as they continue revising their creative writing while doing coding activities with Scratch (Hah & An, 2017), turning their writings into interactive stories with Scratch programming that is visible. Maker activities also allow students to learn social studies lessons in a makerspace that can provide an immersive set of experiences (Barrow Media Center, 2017).

Moreover, maker activities have been found to foster 21st-century skills, such as collaboration, critical thinking, problem-solving, and creativity (Scott, 2015). These skills can be realized by designing collaborative projects based on constructionism and integrating maker projects with technological tools that students learn to operate through hands-on and social-on collaborative construction processes (Kang & Yoon, 2017; Papert, 1980; Valente & Blikstein, 2019).

**Arts Integration**

As the benefits of using arts in STEM are becoming better documented, the movement is now addressing other subjects beyond STEM, such as the arts. STEAM, as one example of arts integration, is the result of a movement at the Rhode Island School of Design (Maeda, 2013). Traditionally, this approach involves two competing values (Catchen, 2013): (a) the purpose of STEAM is teaching the arts and the STEM content in order to deepen students’ understanding of both; and (b) the purpose of STEAM should not be so much to teach the arts but to apply them in real-world situations, leading to deeper learning of STEM subjects.

In this study, as shown in Fig. 3, we adopted the definition of arts integration as “an interdisciplinary teaching practice through which non-arts and arts content is taught and assessed equitably in order to deepen students’ understanding of both” (New Jersey Principals and Supervisors
[NJPSA], 2018, p. 9), echoing the first value mentioned above. When various types of the arts are integrated into other subject matter, they must be intentionally taught and assessed as distinct subject matter, along with the subjects into which they are integrated. That is, the arts should not be treated as merely a decoration or an add-on.

Research has shown a variety of benefits to using arts integration as a pedagogical approach for students as well as educators. For example, use of the arts in STEM classrooms can make classes more enjoyable and more emotionally fulfilling with increased participation and affective engagement in the learning of STEM concepts, which in turn leads to a greater probability of STEM success (Overland, 2013; Riley, 2012). By moving from STEM to STEAM education by adding a technological tool, such as Makey Makey, for example, students can participate in practical innovation through self-expression (Siemon et al., 2016).

For example, in high-needs, low-income middle schools, arts-integrated activities improved student perseverance with problems and tasks in class, increased attention, motivation, engagement, participation, sense of pride, level of amusement and exploration, along with reducing anxiety in school settings, especially during test-taking (An et al., 2020). Moreover, the use of various types of arts, such as music and group drawing, has been found to foster group cohesion (Lindvang & Beck, 2015), enhance collaboration (Thorsted et al., 2015), and engage students in critical inquiry (Hetland et al., 2013) – all important 21-century skills.

For teachers, arts integration offers benefits by providing pedagogical flexibility and an unforeseen conduit for generating elements of higher-order thinking, sparking creativity (An et al., 2020), and creating more diverse learning opportunities and, thus, greater access to STEM for all learners (Catchen, 2013; Martin & Panjwani, 2016).

Notwithstanding these positive outcomes of the arts integration approach, most studies in this area so far have been based on in-person classroom settings (An et al., 2020; Catchen, 2013; Hetland et al., 2013; Lindvang & Beck, 2015; Martin & Panjwani, 2016; Thorsted et al., 2015). To extend the applicability of this approach, this study illustrates how arts-integrated projects can also be meaningfully conducted in an online environment as a team.

**Using a Collaborative Project to Achieve a Team Goal in Online Learning Environments: Maker Activities**

In online learning environments, interaction is a critical factor for the quality of learning and students’ cognitive learning outcomes (Garrison et al., 2001; Swan, 2001). Specifically, in distance education, enhancing academic satisfaction, sense of community, and feelings of connectedness is related to higher student persistence (Rovai, 2002). Interactions among peers and instructors are the key to promoting collaborative learning and a sense of community, which leads to a sense of accomplishment in a group (Kreijns et al., 2007; Mumford & Dikilitas, 2020).

Against this background, the use of online discussion boards was investigated as a primary tool to promote interaction and collaboration in online learning contexts (Curtis & Lawson, 2001; Levine, 2007); however, an asynchronous tool provides interaction between a keyboard and a remote database rather than engaging the hearts and minds of learners via stimuli that can foster emotional connections. Instead, when collaborative and interactive online activities are designed to engage learners’ hearts and minds, learners may develop a feeling of belonging and acceptance and engage in bonding relationships, which in turn increases persistence and learning (Rovai, 2002).

Maker activities, by their very nature, can fill this critical gap through constructive environments offering authentic and practical activities that require regular group communication and peer interaction. However, to date, maker activities have not been recognized as a key component that could enhance collaboration in online environments due to the difficulties of utilizing hands-on materials and minds-on and hearts-on instructional strategies in such an environment. Despite these perceived limitations of maker activities, the present study found positive results by offering maker projects online that promote team building to achieve a shared value (Holmes, 2013) and to connect participants through affective interactions by sharing individual goals and tasks for larger group goals. The establishment of connectedness and social presence through not just social-on but also minds-on and hearts-on learning can alleviate feelings of isolation online (Baker & Watson, 2014; DeWert et al., 2003) and increase confidence and enthusiasm for work (DeWert et al., 2003) and, thereby, address and overcome frequently cited obstacles to online instruction.
**Course Activity Design**

The objectives of this online course, ELCL6450: Programming, Robotics, and Engineering in STEAM, were to teach inservice teachers basic programming concepts and coding skills as well as student-centered collaborative pedagogical strategies for maker projects that incorporate the arts to be applied in their own classrooms. The latter part was emphasized by completing the collaborative orchestra project in an online environment. Since the participants had teaching experience at various K-12 grade levels and had no or little experience in coding, the activities and group projects had to be broad enough to be useful across a wide range of needs and settings.

Table 1 outlines the activities that took place in the course over seven weeks, culminating in the final authentic online collaborative orchestra group project. During the seventh week, teachers played two music pieces and then participated in a verbal reflection, followed one week later by submission of a written reflective essay. The book *Lifelong Kindergarten: Cultivating Creativity Through Projects, Passion, Peers, and Play* (Resnick, 2017) and various articles were required readings in the class.

**Methods**

**Participants**

Thirteen inservice teachers (11 female and 2 male; 3 high school teachers, 5 middle school teachers, 4 elementary teachers, and 1 preschool teacher) were enrolled in the course ELCL6450: Programming, Robotics, and Engineering in STEAM during the fall 2020 semester at a mid-sized state university in northern New Jersey. The teachers’ race/ethnicity included 1 Asian, 2 Hispanic, 8 White, and 2 teachers of mixed race. The teachers’ age ranges were: one above 41 years old: 1; 31–35 years old:

| TMSR Activity for each stage | Aim and description of the lesson |
|-----------------------------|----------------------------------|
| **Opening Activity** With Unplugged Activities, Coding, and Makey Makey Thinking | Conceptual foundation through exploration with an unplugged activity |
| Constrained coding activity & advanced coding activity with an open-ended project | Non-Technological Unplugged Activity Pertaining to Computational Thinking: Discovery Approach As a foundation of knowledge, teachers were introduced to the concept of computational thinking by reading the article “Computational Thinking: What and Why?” (Wing, 2010) and by doing an unplugged activity. Provided with a game, teachers were required to create game rules with step-by-step procedures, which they would later provide to their own students. They also had to create a template with the game’s rules |
| Guided discovery through tinkering with Makey Makey | Constrained Coding Activity Teachers were guided to do three exercises (Minecraft, Frozen, and Artist) available at https://code.org/hourofcode/overview to gain knowledge about programming commands inductively while playing games in a Zoom breakout room in pairs. After completing these activities, teachers reconvened in the main Zoom room and reported what they had learned |

**Main Orchestra Projects**
Table 1 (continued)

| TMSR     | Activities for each stage                          | Aim and description of the lesson                                                                                       |
|----------|-----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Making   | Creating a musical band with coding, Makey Makey, and art making | 1. Basic Overview of Music: Lecture  
A foundational overview of music pertaining to musical notations, different kinds of rhythms, and instrumentation (keyboard, strings, woodwinds, and percussion) was provided by a music educator  
2. Creation of Components for the Orchestra Project  
2-a. Design and create individual paper musical instruments (see Fig. 4): Teachers designed and constructed their chosen instruments using cardboard, construction paper, or any other materials of their choice to make two music pieces. No instructions or parameters were provided on how to design the instruments. It was up to each teacher to design the components, so each person had agency to make their own decisions  
2-b. Create coding for the teachers’ portion of the orchestra:  
Teachers coded their part of the music piece in Scratch for their instruments and connected the paper instruments  
2-c. Build Makey Makey to connect coding and musical instruments (see Fig. 5): Teachers built Makey Makey to connect musical instruments (2-a) and Scratch code (2-b), partially completed during the class in a breakout room on Zoom, and finished the making portion as an assignment  
3. Music and Instruments Used in the Orchestra Project  
3-a. Music: The two music pieces selected for the project were Minuet in G by Johann Sebastian Bach and Habanera from George Bizet’s Carmen. These two pieces were chosen because they are well-known and from two different musical periods, Baroque and Romantic, and the teachers, therefore, were able to experience different styles of music  
3-b. Instruments: The instruments used to play the two music pieces were:  
- Minuet in G by Bach: Flute 1, Flute 2, Clarinet, Double Bass, Cello, Trombone, Bassoon  
- Habanera From Carmen by Bizet: Flute 1, Flute 2, Cello, Double Bass, Clarinet, Saxophone, Trombone, Bassoon  
Two teachers played the same instruments because of the limited options on instrumentation in Scratch; this limitation allowed teachers to work in pairs  
| Sharing  | Group collaboration: Playing the music with coding, instruments, and Makey Makey together in a group | Play Together as an Orchestra in an Online Meeting Room  
All teachers played two songs together in a synchronous learning environment on Zoom while simulating playing instruments made of paper as if they were in a real orchestra (see Fig. 6). The actual musical sounds were created from the Scratch code by linking the conductive objects (musical instruments) with the alligator clips instead of using the computer keyboard. By sharing their artifacts and playing together with the artifacts, teachers achieved the shared team goal in an online environment. The playing of the Minuet in G by Bach as an orchestra may be found at https://www.youtube.com/watch?v=KphJoVDM9RI&t=78s  
| Reflecting | Synchronous team reflection, discussion, and individual reflections | Teachers were encouraged to reflect upon their learning process, experiences, and outcomes by conversing with the entire group on Zoom as well as writing individual reflective essays. In doing so, they strengthened and applied more broadly the learning they experienced in the course (Burke, 2015) by thinking about how they might apply this experience to their classrooms in the future |
9; 26–30 years old: 1; and 20–25 years old: 2. Twelve teachers were employed at public schools and one in private schools. Only 2 of the 13 teachers had taken an undergraduate programming class prior to enrolling in the course. One teacher had learned Scratch during a previous professional development workshop. None of the teachers had experience using the Makey Makey technology prior to taking the course. All seven sessions of the course were taught by the first author of this study synchronously for 2 h and 40 min each week, via Zoom.

**Research Questions**

Using a mixed-methods approach, the study identified the effects of the arts-integrated maker project (virtual orchestra) conducted in a synchronous online environment to support learners’ hands-on, minds-on, hearts-on, and social-on learning, and sought to answer the following questions:

RQ1. How have teachers’ perceived satisfaction and comfort with online courses, connectedness, and emotions changed?

RQ2. What are the teachers’ reflective thoughts and perceptions as learners and teachers who participated in the arts-integrated maker projects in an online learning environment?

**Data Sources**

To answer the research questions, we utilized data collected from two sources: a survey and reflective essays. The survey probed three areas: (a) levels of satisfaction and comfort with online learning, (b) sense of connectedness (Bolliger & Inan, 2012), and (c) emotions about achievement (Bieleke et al., 2021). In the reflective essays, participants examined their thoughts about their learning experiences. All 13 teachers responded to the survey and submitted their reflective essays.
Level of Satisfaction and Comfort With Online Learning

As single indicators (Hayduk & Littvay, 2012), four items were developed by the authors to probe (a) learners’ perceived satisfaction with an online course, (b) the quality of online courses compared to in-person classes, (c) the level of comfort when participating in an online collaborative project, and (d) the level of comfort when participating in online hands-on activities. Participants were asked to record their general satisfaction and comfort level before taking ELCL6450 and how that level changed after they had taken the course and participated in hands-on collaborative online activities.

Connectedness Survey

Two subscales of the Online Student Connectedness Survey (OSCS; Bolliger & Inan, 2012) – Comfort (8 items) and Community (6 items) – were adopted in the current study to measure participants’ perceived comfort level and sense of community before taking the ELCL6450 online course and how their comfort level and sense of community changed after they had taken the course. In particular, the Comfort subscale was designed to assess online learners’ feelings of comfort with expressing their thoughts, sharing questions and difficulties, communicating, and feeling safe. The Community subscale was designed to probe learners’ social and emotional perception with regard to peers and instructors in online courses. The reliability evidence of the subscales was good for both Comfort (Cronbach’s $\alpha = 0.97$) and Community (Cronbach’s $\alpha = 0.96$) (Bolliger & Inan, 2012).

Achievement Emotions Questionnaire

To measure the learners’ achievement emotions, a short version of the Achievement Emotions Questionnaire (AEQ-S) was adopted (Bieleke et al., 2021). AEQ-S is a 28-items instrument for measuring achievement-related emotions in an educational setting, such as enjoyment (4 items), hope (4 items), pride (4 items), anxiety (4 items), shame (4 items), hopelessness (4 items), and boredom (4 items). We adopted 24 items from the AEQ-S, excluding the hopelessness subscale due to its low relevance to this study.

The overall reliability of the AEQ-S scales was lower than that of the AEQ scale ($M_\alpha = 0.85$) but was reported to be satisfactory ($M_\alpha = 0.76$). The scale was not designed for online courses; however, the current authors adopted the AEQ-S survey to measure participants’ feelings of achievement in the ELCL6450 online course compared to other online classes.

Reflective Essay

Participants completed reflective essays to report on their learning experiences at the completion of the virtual orchestra project. The two question prompts in the essay were: “What are your thoughts about arts-integrated maker projects in a playful, sharing, and collaborative learning environment?” and “As a teacher, what are your thoughts on the processes that transpired during the collaborative project?” The directions stated that the assignment was to be five pages long, double-spaced. There was no time limit. The essays were reviewed by the first two authors.
Data Analysis

Survey Responses

To compare learners’ perceptions of online courses before and after taking the ELCL 6450 online course, we applied Wilcoxon signed-ranks tests, a nonparametric counterpart of paired sample t-tests, due to the small sample size. To determine the magnitude of the differences, we calculated Hedges’ g effect sizes because Cohen’s d statistic tends to overestimate population effect sizes when using a small sample size (Borenstein et al., 2009).

Reflective Essays

Two perspectives and approaches were applied for the text-based data using thematic analysis defined as “a method for identifying, analyzing, and reporting patterns (themes) within data” (Braun & Clarke, 2006, p. 79): (a) participants’ perspectives as students taking the online course and (b) participants’ perspectives as K-12 teachers teaching their own students. The first perspective involved participants’ reflections on the learning experience with the orchestra project, focusing on a thematic analysis driven by the authors’ analytic interest in the 4-on learning elements. Thus, the data were analyzed based on the design elements implemented in the study. In contrast, for the second perspective, which involved participants’ reflections as K-12 teachers, the data were analyzed inductively without trying to incorporate a process of coding the data into a pre-existing coding frame (Braun & Clarke, 2006).

For the thematic analysis, the first two authors read the essays independently to identify patterns and themes, and then met online to discuss and compare similarities and differences in the recurring themes inductively (Braun & Clarke, 2006; Patton, 1990). Through an iterative process, themes were developed, and all inconsistencies in the coding were resolved.

Findings

Satisfaction and Comfort

As shown in Table 2, a Wilcoxon signed-ranks test revealed that there was no significant difference in the overall satisfaction with online courses in general compared to ELCL6450; this is probably due to the ceiling effect, considering the high mean scores and the small sample size. However, learners pointed to the better quality of ELCL6450 and expressed a higher comfort level with the online collaboration and hands-on activities than in online courses(s) in general. The effect sizes of the differences were all large, ranging from 0.92 to 1.06.

Connectedness Survey

As shown in Table 3, a Wilcoxon signed-ranks test revealed that participants’ general comfort level with the ELCL6450 online course was significantly higher than their comfort level with online courses in general, with a large effect size (Hedges’ g = 1.25). Similar to the results on the Comfort subscale, teachers’ general sense of community in the ELCL 6450 online course was significantly higher than in online courses in general, with a large effect size of the difference (Hedges’ g = 1.16).

Achievement Emotions

The teachers scored higher on enjoyment, hope, and pride, indicating stronger positive achievement-related emotions, whereas they scored lower on anxiety, shame, and boredom, which means relatively small negative emotions about academic achievement (see Table 4). While teachers scored higher on enjoyment, hope, and pride for the ELCL6450 online course than online courses in general, Wilcoxon signed-ranks tests revealed only significant differences in enjoyment, probably due to the ceiling effect, considering

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**Table 2** Participants’ satisfaction and comfort level with online courses in general vs. ELCL6450

| Perceptions                                    | Online courses in general | ELCL6450: Programming, Robotics, and Engineering in STEAM | Wilcoxon Signed-Ranks Test | Hedges’ g |
|------------------------------------------------|---------------------------|----------------------------------------------------------|---------------------------|-----------|
| Satisfaction with the course                   | 4.08 ± 1.12               | 4.46 ± 0.52                                              | -1.23                     | 0.221     | 0.31     |
| Quality of the online courses compared to in-person courses | 3.00 ± 1.41               | 4.23 ± 0.83                                              | -2.54                     | 0.011     | 0.92     |
| Comfort with collaboration in online courses   | 3.23 ± 1.36               | 4.85 ± 0.38                                              | -2.70                     | 0.007     | 1.06     |
| Comfort with hands-on activities in online courses | 2.92 ± 1.66               | 4.69 ± 0.48                                              | -2.68                     | 0.007     | 1.01     |
the high mean scores and the small sample size. The effect size of the difference was large, with Hedges’ $g = 0.87$. Among the three negative emotions, teachers scored lower on anxiety and boredom for the ELCL6450 online course than online courses in general. However, Wilcoxon signed-ranks tests revealed only significant differences in boredom. The effect size of the difference was large, with Hedges’ $g = 1.54$.

Reflective Essays

In analyzing participants’ reflective essays, the authors organized the qualitative data into two perspectives that guided our analysis: (a) participants’ experiences with the orchestra project as learners, and (b) participants’ reflective implications as inservice K-12 teachers. Within each perspective, the first two authors categorized quotes by the 4-ons – hands-on, minds-on, hearts-on, and social-on – to highlight how the participants reflected on those specific aspects of learning. The participants were not informed of the 4-ons employed in the study; therefore, the quotes reported below from their reflection papers are solely based on their real-world experiences in this online collaborative maker project. Interesting, the reflections address all aspects of the 4-ons, showing how participants interacted with their learning experiences as learners and as teachers.

Reflections on the Learning Experience as Learners

Participants reported how they were engaged physically (hands-on), cognitively (minds-on), emotionally (hearts-on), and socially (social-on) in the simulated orchestra project in an online environment. Their quotes were categorized into six themes, which are a combination of the 4-ons (as shown in Fig. 7). Because the 4-ons were meshed into the project, the quotes addressed the 4-on components in combination, not individually. The six categories with example quotes are presented in Table 5.

Reflections on the Learning Experiences as K-12 Teachers

The second perspective emerging in the reflection papers pertained to the participants’ thoughts as K-12 teachers, whose goal was ultimately to be able to apply their acquired knowledge and skills to their own teaching. Four themes were found from the iterative analyses by the two authors; they are presented with exemplary quotes below.

Collaboration Creates a Comfortable Climate

The teachers pointed out that the collaborative component created a failure-positive environment and promoted comfortable and positive emotions along with increased confidence, which would be applicable for their students. The partnership they built while working toward a common goal of coding and playing orchestra music together led to a felicitous and
playful form of learning. Working with each other toward a shared team goal (i.e., social-on) mediated by coding, making, and music formed a “no-fear environment” and “you can do it” climate. Participants acknowledged the value of the comfortable emotions resulting from the collaborative “social-on” learning. When integrating technology, team-building components promote a sense of presence, as well as feelings of pride and enjoyment in K-12 classrooms.

“The important quality that is needed for this project is to create a no-fear environment. Students should be comfortable with collaborating with their classmates and making mistakes. Making a mistake should not be a negative action, but a learning action.”

“Exposure to this platform of coding and creating entire musical pieces opens a world of possibilities for children that they feel comfortable.”

**Arts-Integrated Project Leads to Minds-on Learning** The teachers realized how music and art are effective in increasing students’ interests and connecting learning with other domains such as programming. Combining coding with the arts can meet the diverse needs and different levels of interest among students, thereby benefitting different types of learners. When a hands-on “crafting component” is added to the combination of coding and arts, learning becomes deeply engaging.

“Since the start of this project I have been thinking about how my students would really love to do a project like this. The students in my school lost their music class two years ago and their art class this year because of budget constraints. My students have a wide variety of interests, with music and art being at the top of their lists. My fourth graders were very intrigued in learning how to code when I shared my math game with them and explained how Scratch works. I was thinking that my students would really enjoy creating something for our Holiday Show in December.”

“Students who do not think of programming as something they are interested in can be engaged with a topic that they do have interest in; for example, arts and music. This provides an alternative way of building a felt need in the programming classroom and can reach out to students who would otherwise suffer from disinterest.”

**Arts-Integrated Learning Promotes Creative Thinking** An arts-integrated learning activity facilitates learners’ creative thinking, which is essential in 21st-century learning. Arts infused into maker projects increases engagement and enjoyment in learning and, more important, “presenting ample artistic freedom to students” helps develop creative thinking.

“We, the educators, are facilitators of creativity, exploration and discovery and this particular project [integrating arts] would allow for this.”

“This project helps develop creative thinking because it provides multiple opportunities for creativity to occur. Artistic models of instruments, selection of song/music, and coding selections (sprite and background) present ample artistic freedom to students.”
Arts-Integrated Learning Increases Access and Lowers Barriers

Teaching music, visual arts, and coding requires instruments, tools, and materials that are not easily accessible in under-resourced low-income schools. From the in-service teachers’ perspectives, this project was valuable as a way to overcome limited funding in real classrooms while providing opportunities to make instruments, play with instruments, code musical pieces, and learn music and coding for all students. The online learning environment increased access to various types of online programs and resources; however, before participating in the project, the teachers were not aware of best practices pertaining to resources for a meaningful activity and appropriate teaching strategies. The project opened up opportunities to provide arts-integrated hands-on learning with reduced concerns relative to resources and funding. Moreover, the project allowed a larger group of students to engage in learning and making.

Table 5 Participants’ quotes regarding their experience in the orchestra projects based on the 4-ons

| Themes                  | 4-Ons | Hands | Hearts | Social | Minds |
|-------------------------|-------|-------|--------|--------|-------|
| Hands-on with Hearts-on| ✓ ✓   | ✓ ✓   | ✓ ✓    |        |       |
| Hands-on with Social-on | ✓ ✓   | ✓ ✓   | ✓ ✓    | ✓ ✓    |       |
| Hands-on with Minds-on | ✓ ✓   | ✓ ✓   | ✓ ✓    | ✓ ✓    |       |
| Hearts-on with Social-on| ✓ ✓   | ✓ ✓   | ✓ ✓    | ✓ ✓    |       |
| Social-on with Minds-on| ✓ ✓   | ✓ ✓   | ✓ ✓    | ✓ ✓    |       |

The hands-on making activity enabled learners to connect to real-life experiences that strengthened their motivation, interest, connection to the world, and sense of ownership.

“Creating these instruments out of everyday materials provided me with a sense of ownership and comfort that I perhaps would not have had if I just looked at a picture of one.”

“Making the instruments from cardboard made it much more fun and interactive.”

Completing a collective performance by creating individual pieces was a pleasant experience, which confirms that hands-on and social-on learning leads to positive emotions.

“I have never been able to carry a tune or read music, but learning how to code beats, measures, rests, and notes on Scratch and through Makey Makey has made me feel like there is a part of the musical realm that I can be a part of.”

“Being able to independently code our sheet music for a collective performance piece was a pleasant revelation.”

The hands-on making project promoted minds-on learning in making the musical instruments, reading music notes, creating Makey Makey, and coding.

“I felt that I could gain an understanding while having fun and being innovative.”

“Scratch allows students to express what they have learned through coding a specific song or verse in a safe and fun way. Incorporating technology and art into a lesson allows a larger group of students to engage in the lesson and express their understanding.”

In the combination of the social-on and hearts-on experiences, learners acknowledged that the group collaboration created less stressful and more positive environments than when working individually.

“Working on this project in class as a group created a less stressful environment compared to trying to do this on my own.”

“Communicating with others about what you’re doing or what worked and didn’t work allows us to reflect and imagine again which keeps the creative learning spiral moving forward.”

Learners actively participated in mindful learning experiences with improved motivation, engagement, positive emotions, and comfort.

“I felt that I could gain an understanding while having fun and being innovative.”

“Scratch allows students to express what they have learned through coding a specific song or verse in a safe and fun way. Incorporating technology and art into a lesson allows a larger group of students to engage in the lesson and express their understanding.”

Learners were deeply engaged in the project while working collaboratively with peers in Zoom breakout rooms and working toward the shared team goal to complete the collective performance.

“When two students are assigned the same instrument, creativity really beams through. Seeing what visions were the same and what were interpreted differently.”

“In a breakout room on Zoom with a task of two people coding the same long musical piece, my partner and I decided to split the lines of music, share our codes with each other, and then copy the codes we were missing by dragging the blocks into our backpacks and drogging it into our own codes. It worked really well working with my partner on Zoom.”
“According to Google, a Yamaha-brand keyboard is $450, a guitar is $200, and a violin is $450. Scratch is free for all! Practically speaking, this is one major reason how Scratch provides access for all students or at large all districts [diverse districts or at large populations] who do not have the financial means [resources or funds] to equip and play with musical instruments. Children can code existing musical pieces using numbers or they can create their own musical pieces. They can experiment with the different pitches of different numbers and the lengths of each note through Scratch. Maybe the next Bach will be born from playing with Scratch!”

“How to build an instrument from household materials pushes the boundaries of my students.”

“Incorporating technology and art into a lesson allows a larger group of students to engage in the lesson and express their understanding.”

**Discussion**

The virtual orchestra project designed based on the TMSR model in this study incorporated various subjects, primarily the arts and coding, with the use of tools as well as facilitation strategies that teachers could apply in their own classrooms. To promote concrete learning experiences with these elements, tools such as cardboard instruments, the Makey Makey computing kit, and the virtual coding program Scratch were used.

Traditionally, arts-integrated maker projects have been regarded as effective in-person learning activities because the design and construction of physical artifacts were at the core of the task. Our goal in this study went beyond that – to deliver hands-on arts-integrated maker projects with coding in an online environment and to promote learners’ engagement, positive emotions, and satisfaction in online settings.

To that end, the authors developed the TMSR model based on the theory of constructionism and utilized online teaching strategies to create felicitous learning experiences. The online facilitation strategies included a collaborative team-building approach to allow learners to become agents who construct their own individual tasks as part of achieving a team goal and share the meaningful artifacts with the team. Results showed that the project increased participants’ satisfaction and level of comfort with online learning, a sense of connectedness, and positive emotions, thereby moving a step closer to human-centered learning (Chen & Lo, 2019).

The inservice teachers who participated in the study reported an increase in their level of satisfaction, perceived quality of online courses, and level of comfort in working with others and participating in the online hands-on project after they completed the online orchestra project with their peers. Because this collaborative team-building approach promoted learners’ interaction with their peers and instructors in a small-group setting in Zoom breakout rooms, as well as with the entire class in the main Zoom room, feelings of comfort and sense of community significantly increased.

The high degree of social interaction provided by collaborative projects with hands-on arts and coding formed positive and optimistic emotions, as confirmed by the results of our AEQ-S survey. For example, of the six achievement emotion constructs measured, enjoyment, hope, and boredom reached significance. Feelings of pride, anxiety, and shame were not significant. Thus, the increased positive emotions of enjoyment and hope and the decreased negative emotion of boredom support our contention that the arts-integrated collaborative project created learning opportunities that made the students feel comfortable and at ease.

The survey findings were further elaborated and supported in participants’ reflection papers. In particular, it was interesting to find that the teachers’ reflections pointed to the 4-ons, hands-on, minds-on, hearts-on, and social-on, even though they had not previously been informed of these aspects. The reflections represented two perspectives: that of the learners in the course and that of teachers who planned to apply this type of project to their own teaching.

Collaborative arts integration with a shared goal-achieving project (hands-on) enabled learners to feel comfortable (hearts-on), supported, and part of a community (social-on), which together led to positive emotions while learning (minds-on). The participating teachers acknowledged that the arts-integrated coding project promoted comfortable and enjoyable learning and appreciated the value of a collaborative online team-building activity to meaningfully engage learners in minds-on and hearts-on learning.

The reflective thoughts presented from the teachers’ perspectives highlighted key ideas for how this project supports the 4-ons and how these components can benefit future students, not only when learning arts and coding, but also for developing creative thinking and increasing access to diverse resources and motivations. In sum, this project demonstrated that the collaborative project integrating the arts based on constructionism enabled participants to successfully experience all aspects of the 4-ons learning in an online environment.

**Implications**

To support the design of quality maker projects that integrate multiple disciplines and engage learners through emotional support and mindful learning, teacher education and professional development should focus on increasing teachers’ pedagogical knowledge and skills about maker learning so they can apply them in their own specific learning contexts. Especially when the online course is designed for inservice
of their goals, as enrolled in the M.Ed. Curriculum and the participants were a homogeneous group in terms of serving perspective, showing how arts-integrated collaborative maker projects can be an equalizing force in education that can improve student learning processes and outcomes and transform the school experience (Gilbride, 2013) by engaging students, increasing their comfort level in class as a team, and developing their creative thinking, while also allowing them to show their unique strengths. Thus, educating teachers on how to incorporate the arts with maker projects using a team-based approach and applying an instructional design framework can have a positive impact on public education in terms of serving all populations.

Finally, we recognize several limitations of this study. Specifically, the sample size was small (13 teachers), and the participants were a homogeneous group in terms of their goals, as enrolled in the M.Ed. Curriculum and Learning program with a STEAM concentration. Yet, as action research, the main purpose of the study was to inform the first author’s own practice rather than making broad generalizations; nevertheless, replication of the study with a larger sample and with a broader population of teachers would help extend generalization of the findings.

Acknowledgements We thank Dr. Sunny Son, organist and music educator, who assisted us in choosing appropriate musical pieces for the orchestra project and for providing an introductory lecture pertaining to basic. We also thank the participating teachers and all of the teacher educators nationally and internationally who tirelessly have taught their own students in an online environment while striving to learn rapidly how to effectively teach online during the COVID-19 pandemic.

Declarations

Ethics Approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of William Paterson University of New Jersey.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Conflicts of Interest Heejung An declares that she has no conflict of interest. Woonhee Sung declares that she has no conflict of interest. So Yoon Yoon declares that she has no conflict of interest.

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Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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