Harnessing Technology for Promoting Undergraduate Art Education: A Novel Model that Streamlines Learning between Classroom, Museum, and Home

Yael Kali, Ornit Sagy, Tsvi Kuflik, *Senior Member, IEEE*, Orit Mogilevsky, and Emma Maayan-Fanar

Abstract—We report on the development and evaluation of an innovative instructional model, which harnesses advanced technologies and local resources (an in-campus museum), to support undergraduate-level art history students in developing the skills required for analyzing artwork. Theory suggests that analyzing artwork requires theoretical knowledge and practical experience gained through critical dialogue and inquiry of original artwork. An instructional model was designed in which technology (website, collaborative docs, and mobile apps) supported streamlining of learning across settings (class, museum, and home) and conducting collaborative inquiry in situ (e.g., museum). Using a design research approach, the model was studied in three aspects: its potential to enable instructors to implement the cognitive apprenticeship instructional approach; its contribution to the students' development of independence and self-efficacy in analyzing artwork; and the contribution of technology to streamlining learning between settings. Data was collected from two enactments of the course. Findings indicate that the instructors gradually faded their modeling and coaching enabling students to become more active, hence the model we designed was largely implemented by the instructors. Furthermore, it supported students' gradual development of independence in practicing the newly learned skills. From the students' perspective, the integrated technologies created seamless learning between the three settings.

Index Terms—Collaborative learning, education, mobile computing

1 Rationale

One of the most challenging aspects of art history education at all levels is helping students develop the skill to analyze artwork. In higher-education, and especially in introductory undergraduate courses, this challenge is exacerbated by the common culture of university teaching, which is mostly based on lectures, and thus, encourages memorization, rather than skill development [3], [24]. Integrating visits to art museums, where students can examine original works in the real context in which they are presented, can enhance such courses and enable students to examine the dimensions, the true colors and the textures of artwork.

Various studies show that introduction of technology into teaching, along with appropriate pedagogical design can support learning in higher education (e.g., [16]). In some of them technology is used to support integration of outdoor learning [23], [33], in which ongoing and ubiquitous learning that transitions between various settings and contexts is explored. For example, Vavoula et al. [33], showed the effectiveness of novel services, provided by mobile phones, which enabled students to gather information in a museum, followed by later analysis and reflection in the classroom.

The goal of this research was to develop and examine an instructional model, which harnesses advanced technologies, local resources (an in-campus museum), and socio-constructivist pedagogies to support undergraduate-level art students in developing the skill to analyze artwork. More specifically, we designed an innovative instructional model so that it would enable us *to explore how technology can support higher education students in the development of their skills to analyze artwork*. Based on a synthesis of the literature review, as presented below, and our previous studies [16], [24], [17], our "higher level conjecture" [26] was that analyzing artwork is a skill that requires both theoretical knowledge and practical experience that is gained through critical dialogue with peers about original artwork, and that innovative use of technology can productively support these processes.

2 Background and Related Work

Research regarding instruction in higher education has shown that the common approach of lecturing is not sufficient when the development of complex skills is sought. This is specifically true when the student population is diversified, as is the case in many undergraduate level university courses [3]. In such contexts, productive teaching requires supporting "non academic" students to use higher cognitive level processes, which "academic" students use spontaneously [3]. For instance, while, "non-academic"

- *The authors are with the University of Haifa, Haifa 31905, Israel. E-mail: yael.kali@edtech.haifa.ac.il, ornit_sagy@yahoo.com, tsvikak@is.haifa.ac.il, {oriti.mog, maayanimage}@gmail.com.*

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students tend to focus on note-taking and memorization when they attend lectures, "academic" students tend to explain, relate, apply and even theorize ideas they hear in the lectures. Since today's classes are more diversified than in the past, with universities opening their doors to more "non-academic" students, teaching should move away from lecturing and include activities that require students to actively engage in these latter higher order cognitive skills—"It's not what teachers do, it's what students do that is important" [3].

The pedagogical approach at the heart of the instructional model designed in the current work is based on three main bodies of knowledge: Socio-constructivist learning (e.g., [25]), cognitive apprenticeship [8], and art history education (e.g., [10]). In the following sections we provide a brief overview of these three bodies of knowledge. We then review relevant literature regarding what is currently known about how mobile technologies can support learning in such pedagogical approaches and specifically, when learning takes place in multiple settings, and issues of streamlining and seamlessness play an important role.

2.1 Socio-Constructivist Learning

Learning, according to the constructivist theory, is an active process in which learners gather, process and interpret information, create connections to prior knowledge and transform information into knowledge [25]. Building on constructivist ideas, the socio-constructivist view of learning emphasizes the social aspect of this process, and claims that an individual's knowledge is constructed, to a large extent, through social interactions with peers. A specific pedagogical approach that emerged from these notions of learning already in the 1980's, but is gaining more and more interest in its technology-enhanced form is cognitive apprenticeship [8].

2.2 Cognitive Apprenticeship

According to the cognitive apprenticeship pedagogical approach [8] learning occurs in a socio-cultural context by observation, imitation and mediation with other learners. This model shows a process in which an expert can help novices gradually develop expert-like skills. The cognitive apprenticeship framework, which has been studied extensively in various disciplines in k-12 settings since its introduction, suggests that the role of the instructor should transform over time through three main phases: *modeling*, *coaching* and *fading-away*. By modeling, the expert makes his/her tacit knowledge visible to the novices. Then, by coaching, the expert scaffolds students' activity. Eventually, in gradually fading away, the expert encourages novices to develop independence. An important feature in implementing cognitive apprenticeship as a pedagogical approach is in bring cognitive processes into the open, which is also referred to as making thinking visible. In that way, students can observe, enact, and practice new ways of thinking and doing with help from the teacher and from other students [8].

The interplay between observation, the use of carefully designed scaffolds, and increasingly independent practice aids novices both in developing metacognitive skills as well as conceptual knowledge needed to advance toward expertise [8]. Learners also have the opportunity to observe other learners with varying degrees of skills, this encourages them to view learning as an incrementally staged process, while providing them with concrete scaffolding for their own progress [8]. The cognitive apprenticeship pedagogical approach is specifically appropriate in educational contexts in which learners are expected to develop practical skills, such as artwork analysis, in the current study.

2.3 Art History Education

In art education, the development of higher order cognitive skills is crucial. Art history students in higher education are required to gradually develop the skills of art historians. In accordance with the view later described by Biggs [3] for higher education instruction, Erickson [10] advocated for learning art history in an active inquiry approach. Following his review of various approaches to teaching art history he claims the third of the following approaches is the most preferable:

1) Exposure to art work. The teacher uses media to expose students to artworks presented with visual aids such as PowerPoint presentations.
2) Presentation of information established by art historians. The information is presented through slide lectures, assigned readings or student reports.
3) An inquiry process. Teaching how art historians reach the conclusions about art work. There is a distinction between art history as information and art history as process. Learning art history as a process helps students develop their own original ideas about art and appreciate conclusions which art historians have already reached.

Erickson [10] claims that art history as a process can be used as an authentic endeavor and suggests integrating this pedagogical approach in art history instruction. Although this view has been claimed for decades, and despite the dearth of publications regarding pedagogy and assessment in the discipline of art history [9], art history is still typically taught by lectures with reproductions presented on slides. Teaching art history as an inquiry process, as Erickson [10] suggests, requires that the students become more active. One of the options to expose students to original artwork and encourage active learning is to integrate museum visits in art courses.

So far we have reviewed the developments in educational research which view learning as a socio-constructivist process. We focused specifically on cognitive apprenticeship as a pedagogical approach that can support skill development, and described how an inquiry instructional approach in art history can support students in developing the specific skill of artwork analysis. Studies from recent years have begun to explore how technology and specifically mobile technology can support learning in each of these pedagogical approaches.

2.4 Mobile Learning and Mobile Technologies

Mobile learning occurs at any time and place where knowledge transfers from one place to another and new learning connections are formed through constant interaction [35]. Mobile devices such as smartphones support this type of learning, allowing portability, transfer of knowledge from place to place and data collection. The concept of mobility, then, has significant physical, technological, conceptual, social, and temporal meaning [28].

In recent years, a large number of studies were reported, focusing on the advantage learning with new mobile technology frameworks. Hwang et al. [14] and Looi et al. [19] analyzed the potential of mobile learning research for designing "seamless learning environments that can bridge both formal and informal learning" and discuss important methodological, technological and assessment issues that concern research regarding formal and informal learning. They conclude that research into seamless learning needs a strong focus on pedagogy, professional development of teachers, co-design of lessons with teachers, a design research perspective and affordable mobile learning devices. Ogata et al. [21] describes SCROLL-a client-server application that enables users to record and share their ubiquitous learning experience. Sung et al. [31] experimented with a prompt-based annotation approach to conduct mobile learning activities for architecture design courses. Liu and Hwang [18] present a paradigm shift from conventional e-learning (the way people use an electronic device, usually a computer with learning technology) through mobile learning (using mobile devices with learning technology, such as PDAs, smartphones and portable computers for learning) to context-aware u-learning (using mobile technology that contains additional sensor devices for technology-assisted context-aware ubiquitous learning) in terms of theoretical and practical variables. It seems that innovative technologies are becoming an integral part of many educational contexts, but that we are only beginning to understand how they serve to enhance learning and teaching processes, and how they can implement pedagogies that reflect our current state of knowledge regarding how learning takes place.

It is also worth noting that the use of mobile technology for learning may be challenging, as reported by Chu [7] who found that students who learned in real-world scenarios that included mobile devices obtained unfavorable learning achievements due to a high cognitive load. Another study that pointed out difficulties in the integration of mobile technologies into educational settings has been described by Wong and Looi [36]. They analyzed the state of the art in mobile learning and pointed out gaps between what is achieved so far and what is needed in the following areas: Combining the use of multiple device types; Seamless transformations between multiple learning tasks; Knowledge integration and synthesis; Encompassing multiple pedagogical or learning activity models. All these aspects, according to Wong and Looi [36] need to be improved.

The promises, as well as the challenges described above regarding the use of mobile learning in educational contexts, call for further research. The capability of mobile technology to streamline learning in various settings intrigued us to further study this aspect. This capability is especially relevant in art education, in which museums play an important learning environment.

2.5 Mobile-Assisted Seamless Learning in Museums

Museums often serve as informal learning environments with inherent advantages such as: nurturing curiosity, leveraging motivation and generating a sense of wonder, interest, and enthusiasm to learn [11]. The museum environment can support active learning of exploration and discovery; the halls are often organized by themes and include diverse artifacts and original artwork that one can learn about via direct experience [33].

In accordance with Erickson's [10] view about productive pedagogies in art education, Paris [22] maintains that museums should be designed in a way that encourages inquiry, construction of meaning through choice, challenge, control and cooperation that will lead to self-discovery and pride in achievements.

Recent studies revealed a variety of advantages to the use of technology in museums, especially the use of mobile technology. In general, technology can enhance the visitors' experience, given that it provides additional information and a different kind of experience [20]. Tallon and Walker [32] refer to the connections made possible by technology. Specify, they view information communication technologies as means that enable learners to link experiences in the museum to learning that occurs elsewhere before or after the visit in the museum.

The mobile technology, specifically, has the potential to support a variety of activities such as exploration, communication and documentation of the experience [13]. It may provide the visitor a personal experience and assistance during the visit. Moreover, it can be used to draw attention to exhibits, to provide the visitor with personal information, to help navigate in the museum and to enrich and expand the social interaction outside the museum [34]. Mobile technology is thus used as a bridge between different learning contexts, not only in the physical sphere but also between personal and social connections of students to history, artifacts and their use [29].

Researchers have embraced the benefits of mobile technology for the purpose of learning and examined them in the museum environment [5], [30]. Various technological tools have been tested in museums: Electronic guidebooks [2], [27], handled devices, such as multimedia phones and PDA's [33], [37]. These kinds of guide systems were used for interactive inquiry learning and problem solving. For example, in the "Musex" project, children worked collaboratively to answer questions about related exhibits using PDA's [37]. Another example is the "Myartspace" project, a service on mobile phones for inquiry learning that allows students to gather information during a school field trip which is automatically sent to a website where they can view, share and present it back in the classroom or at home. The study showed that this information provided resources for effective knowledge construction and reflection in the classroom [33].

To summarize, it seems that technology has the potential to enhance and streamline learning between multiple settings. We were unable to find, though, research that explores the implications of implementing such streamlining technologies with the cognitive apprenticeship approach.

TABLE 1
From Theory to Re-Design

Setting	Cognitive apprenticeship	Art history inquiry	Socio-constructivist approach
Class	Focus on Modeling	Theoretical aspects	N/A
Museum	Focus on Coaching	Collaborative inquiry *in situ*: Active construction of knowledge in small groups (e.g., negotiation of ideas)	
Home	Focus on Fading and student independence		

3 Design of the Learning Environment

3.1 The Context

The current research was carried out in an introductory undergraduate level art history course intended to support art students in developing skills for analyzing artwork. Prior to our intervention the main instructional approach was quite traditional; the instructor usually presented slides of artwork in class and demonstrated how she analyzes them. The course was conducted mostly in class, with two or three visits to an on-campus archeological museum that were guided by the instructor in a similar manner (mainly lectures). The course included five major topics: (1) artwork description, (2) techniques and materials, (3) composition, (4) style analysis and (5) iconography. Students were assessed based on individual assignments—three of them throughout the semester and another culminating one, at the end of the course.

In contrast to the pedagogical approaches described in the literature review above, teaching was mostly based on transmission of information and not on collaborative construction of knowledge as suggested by the socio-constructivist approach. Additionally, students were not involved in in-situ inquiry tasks. In a "cognitive apprentice lens" [8], it seems that the focus of the course, prior to our intervention, was on the instructor's *modeling*, with little *coaching* and no gradual *fading away* to prepare students for the culminating assignment.

A co-design team that included the authors of this paper and two instructors was formed in order to re-design the art course based on the theoretical frameworks described above. As summarized in Table 1, the re-designed course spanned across three settings—class, museum and home (by "home" we refer to any place in which students conduct learning assignments at their own time, out of campus). Learning across those settings was integrative in contrast to the original format in which the museum visits were considered as enrichment. The home assignments were also related to the topics studied in class and in the museum.

3.2 Design of the Revised Course

The main changes that guided the revisions in the course were derived by the theoretical frameworks as follows:

A. *Employing the cognitive apprenticeship approach for a gradual development of students' independence in artwork analysis.* This was carried out through streamlining the learning between the three settings:

- *Class*. Regular class lectures in which the instructors could model the skills of artwork analysis as practiced by art historians

TABLE 2
The Design of One Sequence of Activities and Role of Technology

	Learning setting	Designed activities	Supporting technologies
A sequence of learning sessions in each of the topics	Class-room	**Lecture** - Instructor demonstrates relevant skills, using projected slides with images of artwork (pre-loaded to the course website).	**Course website** - holds preloaded presentations with images of the artwork **Overhead projector**
	Museum	**Lecture** - Instructor demonstrates relevant skills, in front of an original artwork, aided by complimentary slides projected on the wall of the museum. **Team-work** - Students collaboratively work in front of an artwork on an assignment, practicing previously demonstrated skills. Instructor passes between teams, guiding and scaffolding their work.	**Course website** - includes private collaborative spaces for each of the teams. The private spaces store the data recorded during museum visits and contain editable spaces (embedded **collaborative documents**) for collaborative work on assignments. **Overhead projector** **Mobile technology**: • **Handheld visitors' guide** - location aware devices that provide information on artwork together with access to course website, assignments and applications. • **Tumblr** - handheld app to record data (audio, video, or still images) during museum visits. The recorded data is automatically transferred to the teams private collaborative space.
	Home	• **Teamwork** - Students continue working on the assignment collaboratively. They are encouraged to revisit the artwork in the museum for additional collection of data. The instructor provides formative feedback.	**Course website** - as described above.
Final, individual, culminating assignment			

- *Museum*. Museum visits in which students could practice the learned skills with the instructor's coaching.
- *Home*. Online home assignments in which the instructor could provide formative feedback.

B. *Collaborative inquiry of artwork*. Informed by the socio-constructivist approach and the recommendation in the literature to teach art history in an inquiry approach, groups of three to five students were given collaborative assignments that required independent inquiry of artwork. Class lectures were designed to provide the theoretical foundations needed for the inquiry that was carried out in-situ during museum visits. Parts of the inquiry process were carried out by the groups of students at home.

Coaching was achieved by instructors' scaffolding of students' collaborative inquiry work during museum visits and by providing formative feedback on the collaborative assignments.

Technology played a crucial role in this redesigned version of the course. Table 2 details the designed activities in each of the settings and the technology that was used to support them.

The class lectures were very similar to those in the original format of the course. The museum visits consisted of two parts; they were initiated with a short lecture (as in the original format), but were followed by active teamwork in analyzing artwork. The teamwork was scaffolded by instructions in the course website which was available to students through mobile devices (as we further explain

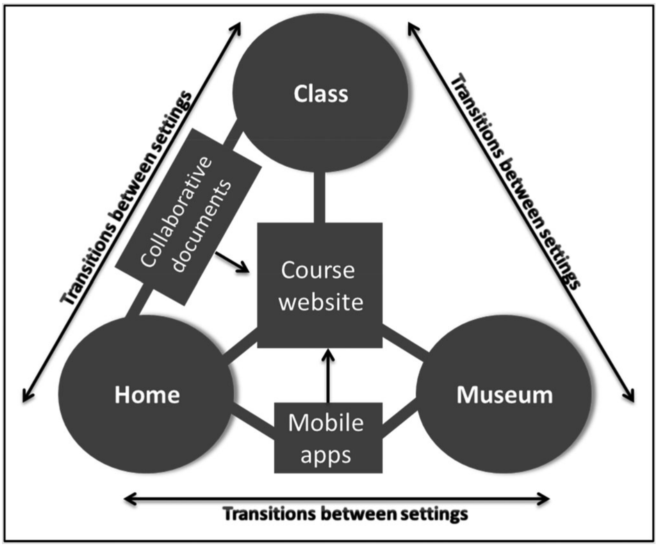

Fig. 1. The role of technology in streamlining learning across settings.

below) and by the instructor who passed between the teams to provide assistance. The first two course assignments were fully collaborative, the third was partially collaborative and the final, culminating assignment remained as individual work, as it was in the original format.

3.3 Supporting Technologies

The only technological tool used in the original format of the course was an overhead projector. The course redesign included the development of a new learning environment that was comprised of three main components: a course website, a set of collaborative documents embedded in the website, and a set of mobile applications. Fig. 1 displays how these three components were used for streamlining the learning between the different settings, and the central role of the website in this process.

Following is a more detailed description of these three components.

3.3.1 The Course Website

Google Sites was used as a main infrastructure for developing the course website, enabling the use of mobile devices and the embedding of collaborative editable documents and additional external resources. The course website played three major roles:

A central repository for course material. Instructors uploaded course resources such as slide presentations, documents, articles, movies and instructions for course activities.

A meeting point for team collaboration. Teams had private editable collaborative spaces that were part of the course website. These areas contained forums and links to collaborative documents (see below) enabling collaboration and communication among team members as well as with the instructors.

A focal point for streamlining the learning across the settings. Data collected through mobile apps during museum visits (photos, clips, audio-recordings, notes) was transferred automatically to the teams' collaborative spaces, connecting between the museum, home and class settings.

Fig. 2. Mobile visitor guide screenshots.

3.3.2 Collaborative Documents

As mentioned above, each of the team spaces was linked to a set of editable collaborative documents that enabled a joint effort of knowledge construction. Google docs were used to allow simultaneous work of several group members. Learning between teams was encouraged by granting viewing permissions to all of the teams' collaborative documents. Instructors had editing permissions allowing additional scaffolding by providing formative feedback.

3.3.3 Mobile Technology

Mobile technology was based on two apps that served two main purposes: (1) Handheld visitor guide providing just-in-time knowledge, and (2) Tumblr, aiding in streamlining learning between settings:

Handheld visitor guide providing Just-in-time knowledge. During museum visits, students had access to a mobile visitor guide application that provided relevant short multimedia presentations regarding the museums' artifacts [17]. This application was part of a location-aware system. When a point of interest is detected by the system it presents users with an aerial image containing a selection of nearby objects for which information is provided (marked in yellow on the left side of Fig. 2). Selection of a specific object and a question of interest results with a one-minute multimedia presentation answering that question (Fig. 2 on the right). For this study, the system was adapted to the course content by adding addition multimedia presentations and defining new points of interest according to the artwork studied as part of the course.

Tumblr aiding with streamlining learning between settings. Tumblr enabled students' documentation of their thoughts and ideas about relevant objects for further analysis at home. Once data was written, recorded or photographed, it was automatically stored on a Tumblr page that was embedded in the team space. The Tumblr application was chosen because of its seamless connection with the course website, the variety of media input types that it provides and the additional capability of adding a short description to the inputted content.

4 Methods

4.1 Methodological Approach

The goal of the study, as described above, was to explore how technology can support higher education students in developing their skill to analyze artwork. To achieve this goal we decided to use a design research approach. Design

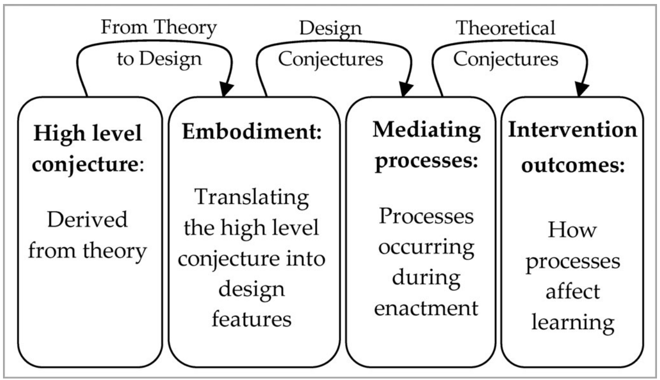

Fig. 3. Generalized conjecture map (adapted from Sandoval [26]).

research involves a dual objective of improving design of learning environments while contributing theoretical knowledge regarding learning in the specific contexts these environments are designed for [1], [15]. Since the learning environment studied in design research embeds an innovative pedagogical means to address a certain educational issue (often using advanced technologies), studying how the design impacts learning processes enables testing "high-level theoretical conjectures" that are embodied within the design [26].

To make these conjectures visible, and illustrate how our conclusions were made in this research, we used Sandoval's [26] "conjecture mapping" approach, which provides an "argumentative grammar" for design research. This technique enables mapping the way high-level conjectures are translated into design features, and how "design conjectures" and "theoretical conjectures" can be articulated and studied. Fig. 3 illustrates the constructs of a generalized conjecture map, as described by Sandoval [26].

As stated in the rationale, the high level conjecture in this research was that analyzing artwork is a skill that requires both theoretical knowledge and practical experience that is gained through critical dialogue with peers about original artwork, and that innovative use of technology can productively support these processes. This conjecture was embodied into our design, as explained above, through three main design features: (a) streamlining the learning across settings: (class—appropriate for theoretical discussions; museum—appropriate for in situ dialogic inquiry; and home—appropriate for online collaborative work), (b) conducting collaborative inquiry in situ, and (c) technological support (including the website, collaborative documents and the two mobile apps).

Our design conjecture was that these features would support instructors to gradually fade away their guidance and enable students to become more and more active and independent in analyzing artwork. Our theoretical conjecture was that due to the processes supported by technology, students will gain self efficacy and independence in analyzing artwork and produce improved artifacts. Fig. 4 illustrates the mapping of these conjectures.

These conjectures assisted us in defining the following research questions:

1) What is the potential of the course model, with its underlying technology and embedded pedagogical approach, to enable instructors to implement the cognitive apprenticeship instructional approach? (referring to design conjecture 1)
2) What was the impact of various course features on students' perceptions of their learning, and how did they view the role of technology in this regard? (referring to design conjecture 2)
3) How did the learning and teaching processes that were afforded by the course model (and specifically the cognitive apprenticeship features) contribute to students' independence and self-efficacy in analyzing artwork? (referring to the theoretical conjecture)

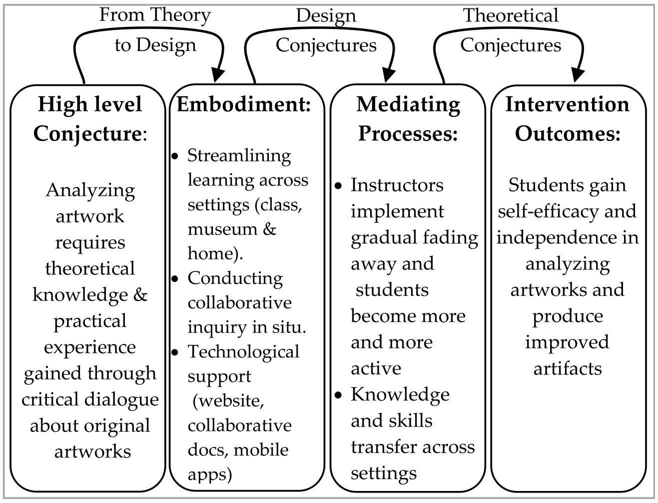

Fig. 4. Conjecture mapping of the current research according to [26] approach.

4.2 Data Sources

The study took place at the department of Art History, during two consecutive years, in two enactments of the course. A total of 108 students and two instructors participated in the study. The instructors were faculty members with extensive experience as art historians. The first enactment took place in 2012 ($N = 62$) and the second in 2013 ($N = 46$). Each enactment included three groups of students, who learned the course separately.

Five types of data sources were used to collect data: observations, student artifacts, interviews with students, interviews with instructors, and a questionnaire, as described below.

Observations. Non-participatory observations have been conducted during the first enactment of the course in 70 percent of the lessons taught by both instructors (including lessons taught in the museum). The lessons were recorded and transcribed.

Artifacts. Three assignments (two collaborative and one semi-collaborative) were recorded in the teams' collaborative documents. A fourth assignment was submitted independently by the students and did not include any formative feedback from the instructor. We analyzed only the two collaborative assignments as they included students' written analysis combined with the instructors' feedback.

Interviews with students. Three in-depth semi structured 20-min phone interviews with randomly selected students were conducted at the end of the course. During the first part of the interview students were asked about their general impression from the course and how the course format affected their learning. During the second part of the interview they were asked about their opinion about the sequence of learning and the role of technology in creating a sense of continuity between class, museum and home. The questions in the interview were asked gradually. The interview started with a general question without mentioning the use of technologies in the course. The interviewees described the course experience in their words without any intervention of the interviewer. More specific leading questions were asked only in cases in which students did not comment on the connection between class-museum-home and the role of technology in this connection. Examples of questions asked during the interview include: What is your impression of the overall course? Was the course different than other courses and if so, in what ways? Did you feel that there was a connection between what you learned in the classroom, and at the museum? Did the use of various technologies in the course help maintain a connection between learning in the classroom, museum and home? If so, in what ways?

Interviews with instructors. Feedback from the instructors was collected via a one-hour open-ended interview with both instructors after the second enactment. The interview was audio taped and transcribed. During the interview the instructors were asked about their general impression of the course and its re-design. They were also asked to reflect about the impact of technology on their teaching and difficulties they encountered along the course.

Questionnaires. A questionnaire with two sets of Likert-type questions were given to students in the last lesson:

1) *Design-feedback questions on a scale from 1-5*—inquiring about students' view of the contribution of each of the course features to their learning. Questions were divided into four major topics; Class lessons, Guided visits at the museum (pedagogy), Guided visits at the museum (Technology) and Learning outside the class. Of the features mentioned inter alia were: Using presentations in class, guidance and assistance from the instructor during teamwork, group spaces, lecturers' feedback on assignment in collaborative documents.
2) *Usability of the technology (Course website, Tumblr, and the course as a whole)*—System Usability Scale (SUS) questionnaire [4] on a scale of 0-5 with 10 statements, alternating between positive and negative are rated and then a score between 0 and 100 is calculated. (where scores of 70 and above are considered acceptable).

4.3 Data Analysis

The transcriptions of the recorded lessons were separated into time segments based on the active party and nature of activity as shown in the rubric in Table 3. These time segments were then categorized based on the instructor's roles in the cognitive apprenticeship framework—modeling, scaffolding and fading away (indicated by a change in the active party, from instructor to student).

TABLE 3
Rubric for Categorization of Activities

Active Party	Activities / Texts	Category
Videotaped observations during lectures—analysis based on time fragments		
Instructor	• Instructor illustrates how she analyzes art • Instructor presents a new viewpoint	Modeling
Instructor	• Instructor asks directing questions • Instructor answers students • Instructor corrects student's idea • Instructor repeats, and emphasizes a student's idea	Scaffolding
Students	• Student answers instructor • Student asks a question	Student Activity
Written (online) collaborative assignments—analysis based on number of words		
Instructor	• Formative feedback text	Scaffolding
Students	• Answer to assignment text	Student Activity

The "home" setting was analyzed using students' written collaborative assignments. These artifacts were divided into segments of text based on the active party (student or instructor). Instructor feedback segments were categorized as "scaffolding" while students' segments were categorized as "student activity" (Table 3).

Following Chi's [6] approach for quantifying verbal analysis, the time segments of the observed lessons were accumulated per lesson and per category, and the percentage of time the instructor spent in each of the roles was calculated. In the same way, the percentage of text representing scaffolding versus students' text was also calculated.

The transcriptions of the interviews were divided into utterances and categorized based on two identified themes: Indications of learning, self-efficacy, and gaining independence that were related to: (a) streamlining of learning between settings, and the role of technology to support this process; (b) the cognitive apprenticeship approach (modeling, scaffolding, and fading). Altogether 99 utterances were analyzed. Since no significant differences were found between the categories that emerged from the interviews with the three students, these were analyzed as a whole, to represent students' views regarding their learning experience in the course.

Data from the questionnaires was analyzed using descriptive statistics. The two enactments of the course were analyzed as one group since there was no significant difference between them.

5 Findings

The findings are presented in the following sections according to the three research questions (and conjectures).

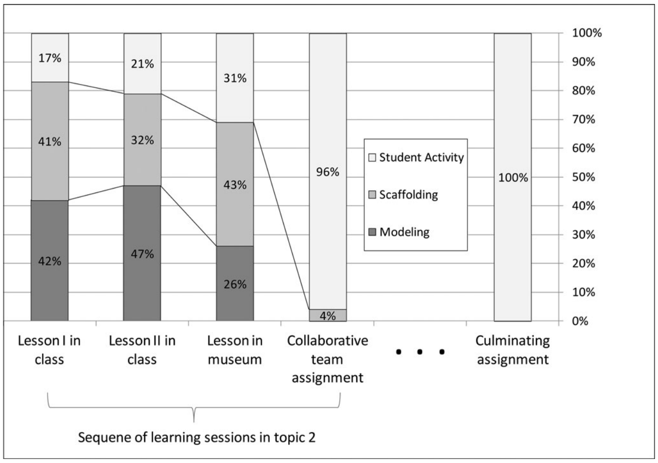

Fig. 5. Distribution of cognitive-apprenticeship roles taken by instructor 1 during the first sequence of learning session in topic 1.

5.1 Impact of the Model on Teaching Processes

What is the potential of the course model, with its underlying technology and embedded pedagogical approach, to enable instructors to implement the cognitive apprenticeship instructional approach? (Exploring design conjecture 1)

The answer to this question is based on the analysis of the observations, student artifacts and the interviews with students. Figs. 5 and 6 represent the distribution of cognitive-apprenticeship roles the two instructors took in different course settings (Fig. 5 represents these roles for instructor 1 during the first sequence of lessons and Fig. 6 represents these roles for instructor 2 during the second sequence of lessons). Both figures show a similar pattern—instructors gradually decreased their own activity (modeling and coaching), to enable students to become more active. In both cases students became more active during museum visits compared to the lessons conducted in class and much more active as they worked on their collaborative assignments. This gradual transition was made possible by the instructors, as they "faded away" their scaffolding and encouraged students' independent work. It is important to note that even though the course design attempts to lead towards gradual fading of scaffolding, the resultant processes depend to a large extent on the instructors that enact the design. For example, instructors may provide different levels of coaching during group collaborative inquiry at the museum (possibly even none).

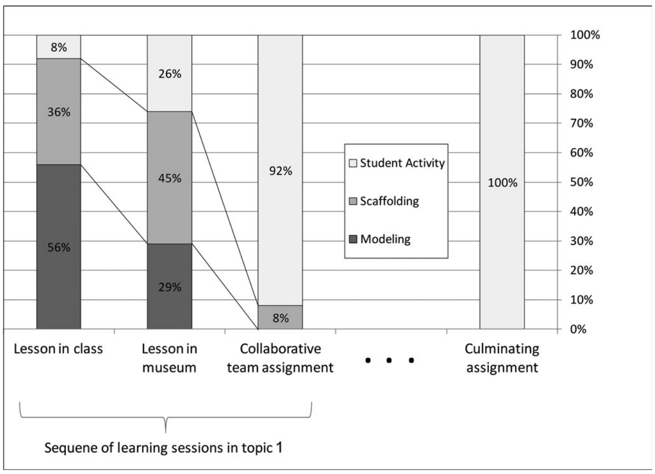

Fig. 6. Distribution of cognitive-apprenticeship roles taken by instructor 2 during the second sequence of learning session in topic 2.

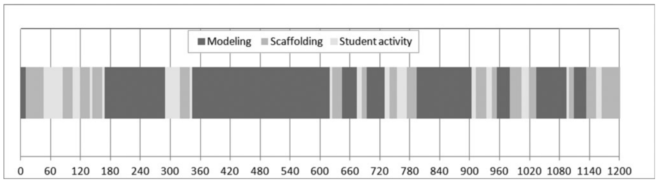

Fig. 7. Shifting roles during 20 minutes in class lesson (instructor 1).

Figs. 7 and 8 show that the instructors, even during classroom sessions intuitively shifted between modeling how they analyze artwork and coaching (eliciting students' questions and guiding them in observations and interpretations). These findings illustrate the nature of teaching in a cognitive apprenticeship approach with a constant dynamic shift between instructors' roles. This was specifically evident in the first instructor's teaching. To summarize the answer to the first research question—the redesigned model, supported by the technologies, encouraged both instructors to implement teaching in a cognitive apprenticeship approach. It enabled them to shift between roles of modeling, scaffolding and fading in a dynamic manner changing over time towards more independent work by students.

5.2 Contribution of Course Features to Learning

What was the impact of various course features on students' perceptions of their learning, and how did they view the role of technology in this regard? (referring to design conjecture 2)

To answer this question we analyzed two data sources (a) the design-feedback data from the questionnaires, and (b) relevant interview data.

Analysis of the data collected using the questionnaire indicated that students viewed all the course features as contributing to their learning, with values ranging between 3.5-4.5. As described in more detail in the next section that refers to the contribution of the course design to the streaming of learning, the course website was considered as an important enabler.

The SUS results (Fig. 9, normalized to 100 percent) indicate that the course website was viewed by students as friendly and easy to use. This is aligned with further findings (see below) showing that both students and instructors, mentioned in interviews that the course website was an important contributor in streaming learning between settings. The usability of the mobile apps, Tumblr and the museum guide application were perceived as poor, hence their real contribution may have been underestimated. These findings are further discussed.

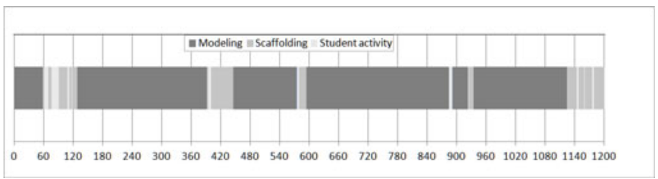

Fig. 8. Shifting roles during 20 minutes in class lesson (instructor 2).

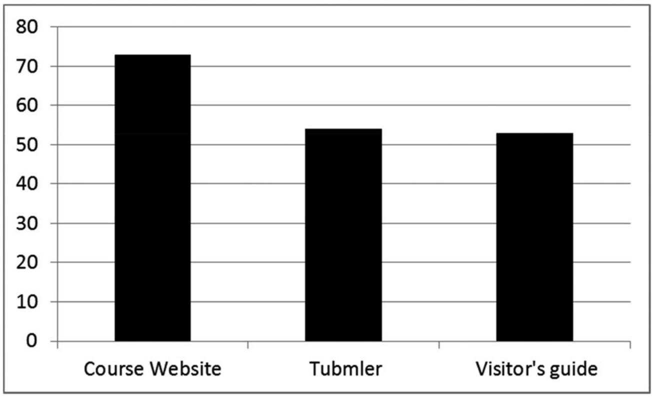

Fig. 9. System usability score.

Since we were specifically interested to know to what extent students found the streamlining of learning between contexts useful for their learning, and how they viewed the role of technology with this regard, we used the interview data to examine this. As can be seen from Table 4, the utterances that could be related to this aspect indicate that in general, students viewed the mobile technology, the collaborative documents and the course website as contributing to streamlining the learning between the multiple settings.

These findings indicate that students were aware of the information flowing between the different settings. They viewed the technology in general, and specifically the course website, as enablers for this flow. In other words, from the students' perspective, the integration of technologies in the design of the course, and specifically the course website, helped them to bridge the gaps between learning in class, museum and at home.

5.3 Self-Efficacy and Independence

How did the learning and teaching processes that were afforded by the course model (and specifically the cognitive apprenticeship features) contribute to students' independence and self efficacy in analyzing artwork? (referring to the theoretical conjecture)

The analysis of student interviews indicated that 31 of the students' utterances had to do with our application of the cognitive apprenticeship approach in the model. The categories that emerged from analysis of these utterances indicated that most of them can be interpreted in terms of self-efficacy and independence in analyzing artwork, as illustrated in Table 5.

These utterances show how students gradually learned the skill to analyze artwork and became independent in doing so. They adopted ways of thinking that the instructor modeled in class and at the museum: *"I just tried to imitate her when I worked on my own"*. They developed their thinking with their peers during online teamwork: *"I learned very well from others, even from their mistakes"*. The instructor's face-to-face scaffolding (in class and at the museum) seemed to have played an important role too: *"The instructor doesn't say 'well... this is what needs to be done'. Rather, she asks 'what do you think?'... At first, it was a little hard for me...But eventually... I understood that... it is very helpful for understanding"*. Students indicated that the fading of the scaffolding was challenging for them *"We analyzed artwork in class, right? But when I got to the [online] home assignments then suddenly I was missing step-by-step instructions"*. But we can learn from many of the utterances that students gradually overcame these difficulties and that their self-efficacy and independence increased as they based their independent work on previous modeling and scaffolding: *"If there weren't the first two exercises as a group, I would not know how to go about in working on the [final] project"*.

All these processes, which encouraged students in developing their skills and in gaining the self-efficacy required to become independent in analyzing artwork, were largely supported by technology that enabled the streamlining of learning between settings, as indicated in Table 5. In fact, students' outcomes, as viewed by the instructors were of higher quality than expected by these two experienced instructors.

From the interviews conducted with the instructors, there is a general impression that the course, in its new structure and the use of technology were successful. They mentioned favorably several elements:

1) The collaborative work with Google docs.
2) Collaborative teamwork.
3) Museum visits and the use of mobile apps.
4) Active learning.

According to the instructors, these elements have increased students' involvement in the course and improved

TABLE 4
Students' References to Technology as a Support for Streamlining Learning

Categories	Sub-categories	Example utterance
Technology as support for streamlining (29)	Mobile technology (14)	*"Two first assignments were on the same artwork, so one of the girls took pictures and uploaded them to the site, I filmed it with my cell phone, so that I can look at it at home."*
	Collaborative documents (5)	*"I can tell you that working together as a group on Google docs was very convenient, and helped us to continue to work online on the assignment that we started at the museum"*
	Course website (10)	*"The site helped because it described all previous and forthcoming lessons. There were also details about what we are going to learn when, and where. It helped us understand what we are actually talking about or the chronological sequence that exists [in the course], the whole program... so it helped."*

TABLE 5
Categories and Subcategories in Theme 1

Cognitive apprenticeship learning experiences		
Categories	Sub-categories	Example utterance
Modeling (5)	Learning and gaining independence from instructors' modeling	*"When we learned in the class and in the museum, I just tried to follow the way she* [the lecturer] *works—starting from the way she talked about art, how she began describing and how she continued to analyze. Then I just tried to imitate her when I worked on my own"*
Scaffolding (17)	Learning and gaining self-efficacy (teamwork as scaffolds)	*"When we did the analysis work in groups it taught me a lot. Because each one responded and we referred to each other, it taught me a lot. In general—I learned very well from others, even from their mistakes. I also learned from the different directions they took in the analysis work"*
	Learning and gaining self-efficacy (instructor's guidance as scaffolds)	*"The instructor doesn't say: ' well... this is what needs to be done. Rather, she asks 'what do you think?' Then, everyone says what they think and then she says: ' well, yes. So do you understand?' At first, it was a little hard for me but I got used to it...But eventually at some point it changed...I understood that if you participate it is very helpful for understanding.*
	Challenges students had to overcome in gaining independence	*"We analyzed artwork in class, right? But when I got to the [online] home assignments then suddenly I was missing step-by-step instructions"*
Fading away (9)	Gaining self efficacy and independence: Students' building on previous modeling and scaffolding	*"If there weren't the first two exercises as a group, I would not know how to go about in working on the* [final] *project"*

their learning and their analytical skills. Both instructors indicated that at the beginning of the course they were somewhat intimidated by the intensive use of technology. They said that they were concerned about not having enough knowledge and skills to use the new technologies (for example: how to update the content on the course website). They didn't know what to expect having those drastic changes in the course. They also expressed worries about the students' reaction and hoped the technology would not become an inhibitor. However, at the end of the course, as they both claimed in the interview, they were not only satisfied about the use of technology, but also enthusiastic about it. They were very pleased with the technological environment which enabled them to follow the collaborative work of the students. Their access to the collaborative documents of the students enabled them to easily provide feedback, which students used to improve their answers and submit higher quality work. The instructors also found it extremely useful to use the website in class in order to bring up and discuss exemplary work of students. The use of these artifacts, which represents student analysis of artwork documented in the museum with mobile apps, and then collaboratively analyzed online, and streamlined to the website, illustrates the seamless flow of knowledge between the three settings.

Overall, the instructors' feedback indicated a very positive attitude toward the set of technologies used in the model. It seems that despite their worries, eventually the technology supported their teaching.

The instructors also mentioned that the new design of the course as a whole had an impact on the quality of the exercises submitted by the students and on their achievements in general (compared with the course as it was taught prior to our intervention with the new design and compared with other courses they teach). Finally, since following the described intervention, the instructors taught the course in the same format on their own, and indicated that they will continue to do so in the future. They also indicated that they began using collaborative documents in other courses, and intend to complement that with mobile technologies.

6 Discussion

As Sandoval [26] describes, "Design research typically aims to create novel conditions for learning that theory suggests might be productive but are not common or well understood" (p. 22). We aimed to explore how technology can support higher education students in the development of their skills to analyze artwork. We based our high level conjecture (see Fig. 4) on three main bodies of knowledge to suggest that socio-constructivist instruction, with cognitive apprenticeship approach and inquiry tasks in-situ will support the development of students' skills in analyzing artwork. Based on this conjecture we designed an innovative instructional model that enabled streamlining of learning across settings (class, museum & home) to enable instructors to: (a) model their expertise (mainly in class), (b) scaffold student practical work in their collaborative inquiry *in situ* (mainly at the museum), and (c) fade their coaching (mainly by requiring students to conduct independent analysis, and by providing feedback at the home online setting).

As Hoadley [12] explains, the mediating processes—i.e., the actual happenings that occur during enactment, depend on countless factors, and should be regarded as dependent factors, or outcomes of the design. Thus, our design conjectures (Fig. 4) were that the design would lead to: (a) instructors implementing gradual fading away and students becoming more and more active, and (b) knowledge and skills would transfer across settings. Our theoretical conjecture was that these mediating processes may result in increased self-efficacy and independence of students in analyzing artwork and producing improved artifacts.

Our findings show that indeed, the course re-design led to instruction that, through modeling and coaching allowed gradual fading away, as hypothesized by the first part of the design conjecture. Students expressed their satisfaction from this model. Their utterances imply that the modeling and coaching helped them in the fading away stage. Students found the collaborative teamwork helpful at both the museum setting, in which they documented their collaborative inquiry, in situ, and at home, where they collaboratively delved deeper to analyze the artwork they documented. The collaborative work, starting in-situ and continuing online, which enabled instructors to provide feedback, but still, gradually fade their coaching, served an important part of the model, leading to gradual gaining of independence by students, and substantiating our theoretical conjecture.

In relation to the second part of the design conjecture, our findings indicate that the set of technologies used in the model enabled the implementation of the new design and supported the streaming of information between the three learning settings—the class, the museum, and home. Students had a sense of continuity between the three learning settings, and knowledge passed between them.

Therefore, as both the design and the theoretical conjectures were verified, we can argue that:

a) The instructional-model with its underlying technological infrastructure, served as a key enabler for the instructors to provide students with opportunities to practice their skills with their guidance.
b) Eventually, these experiences enabled students to develop independence in analyzing artwork, as expressed in the quality of the culminating assignments and by the evidence provided by the instructors in their interviews.

It is important to note that the use of technology as part of this specific course (and in the Humanities department in general) was a dramatic change, especially when combined with the pedagogical change. The fact that the mobile aspect of the model was not perceived by students as a major contribution to their learning might be due to its low usability. Further research, with improved design is required to better understand the specific potential contribution of the mobile technologies in the model, which might not have been exploited in the current study.

It is interesting to note that unlike the paradigm shift suggested by Liu and Hwang [18]—towards moving from e(lectronic)-learning to context aware u(biquitous)-learning, in our case, face-to-face learning was empowered with components of e-learning, m(obile)-learning and u-learning, each contributing to the streamlining of learning between settings and the overall value of the course.

7 Conclusions and Suggestions for Further Research

The goal of this study was to develop and examine an instructional-model, derived from theory, which harnesses innovative technologies and local resources (an in-campus museum), to support undergraduate-level art students in developing the skills required for analyzing artwork.

Our findings indicate that the model we have developed has the potential to promote learning that emphasizes students' skill development while integrating a variety of learning environments coherently. This instructional-model can also be applied to other disciplines that seek to develop various skills among learners and in which collaborative in-situ inquiry is desired as a learning approach. This study also contributes to the understanding of the dynamics and the pace of the instructor's role-changing in cognitive apprenticeship processes (modeling, scaffolding and fading away). The scaffolding was found as essential for learning. In this regard, it would be beneficial to study refined designs for providing scaffolding at different stages as different instructors may offer varying levels of guidance and feedback. It could be interesting to examine whether more formative feedback on the collaborative assignments would lead to even better outcomes in terms of students' independence and self efficacy. Technology played a key role in the implementation of this model, however, the way to use technology should be considered seriously; further research is required to develop criteria for choosing appropriate tools and for designing features that use the added value of technology to support the specific type of learning that is sought. Moreover, technological support has to be carefully designed, to ensure its usability and acceptance by the target audience.

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References

[1] S. A. Barab and K. D. Squire, "Design-based research: Putting a stake in the ground," *J. Learning Sci.*, vol. 13, no. 1, pp. 1–14, 2004.
[2] C. Bartneck, A. Masuoka, and T. Takahashi, "The learning experience with electronic museum guides," *Psychology Aesthetics Creativity Arts*, vol. S, no. 1, pp. 18–25, Aug. 2006.
[3] J. Biggs, "What the student does: Teaching for enhanced learning," *Higher Edu. Res. Develop.*, vol. 18, no. 1, pp. 57–75, 1999.
[4] J. Brooke, "SUS: A quick and dirty usability scale," in *Usability Evaluation in Industry*. P. W. Jordan, B. Thomas, B. A. Weerdmeester, and I. L. McClelland, Eds. London, U.K.: Taylor & Francis, 1996, pp. 189–194.
[5] K. Charitonos, C. Blake, E. Scanlonand, and A. Jones, "Trajectories of learning across museums and classrooms," in *Proc. Transformative Museum*, Roskilde, Denmark, May 2012, pp. 22–25.
[6] M. T. Chi, "Quantifying qualitative analyses of verbal data: A practical guide," *J. Learning Sci.*, vol. 6, no. 3, pp. 271–315, 1997.
[7] H. C. Chu, "Potential negative effects of mobile learning on students' learning achievement and cognitive load—a format assessment perspective," *Edu. Technol. Soc.*, vol. 17, no. 1, pp. 332–344, 2014.
[8] A. Collins, J. S. Brown, and S. E. Newman, "Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics," in *Knowing Learning and Instruction Essays in Honor of Robert Glaser*, L. B. Resnick, Ed. Hillsdale, NJ, USA: Lawrence Erlbaum Associates, 1989, pp. 453–494.

[9] K. Donahue-Wallace, L., La Follette, and A. Pappas, *Teaching Art History with New Technologies: Reflections and Case Studies*. Cambridge, U.K.: Cambridge Scholars Publishing, 2008

[10] M. Erickson, "Teaching art history as an inquiry process," *Art Edu.*, vol. 36, no. 5, pp. 28–31, Sep. 1983.

[11] C. Faria and I. Chagas, "Investigating school-guided visits to an aquarium: What roles for science teachers?" *Int. J. Sci. Edu., Part B: Commun. Public Engagement*, vol. 3, no. 2, pp. 159–174, 2013.

[12] C. M. Hoadley, "Methodological alignment in design-based research," *Edu. Psychologist*, vol. 39, no. 4, pp. 203–212, 2004.

[13] S. Hsi, "The electronic guidebook: A study of user experiences using mobile web content in a museum," in *Proc. IEEE Int. Workshop Wireless Mobile Technol. Edu.*, Aug. 2002, pp. 48–54.

[14] G. I. Hwang, C. C. Tsaiand, and S. J. Yang, "Criteria, strategies and research issues of context-aware ubiquitous learning," *Edu. Technol. Soc.*, vol. 11, no. 2, pp. 81–91, 2008.

[15] Y. Kali, "The design principles database as means for promoting design-based research," in *Handbook of Design Research Methods in Education: Innovations in Science, Technology, Engineering, and Mathematics Learning and Teaching*, A. E. Kelly, R. A. Lesh, and J. Y. Baek, Eds. Mahwah, NJ, USA: Lawrence Erlbaum Associates, 2008, pp. 423–438.

[16] Y. Kali, R. Levin-Peled, and Y. Dori, "The role of design-principles in designing courses that promotes collaborative learning in higher-education," *Comput. Human Behavior*, vol. 25, no. 5, pp. 1067–1078, Sep. 2009.

[17] T. Kuflik, O. Stock, M. Zancanar, A. Gorfinkel, S. Jbara, S. Kats, J. Sheidin, and N. Kashtan, "A visitor's guide in an "active museum": Presentations, communications, and reflection," *J. Comput. Cultural Heritage*, vol. 3, no. 3, article 11, 2011.

[18] G. Z. Liu and G. J. Hwang, "A key step to understanding paradigm shifts in e-learning: Towards context-aware ubiquitous learning," *Brit. J. Edu. Technol.*, vol. 41, no. 2, pp. E1–E9, 2010.

[19] C. K. Looi, P. Seow, B. Zhang, H. I. So, W. Chen, and L. H. Wong, "Leveraging mobile technology for sustainable seamless learning: A research agenda," *Brit. J. Edu. Technol.*, vol. 41, no. 2, pp. 154–169, 2010.

[20] A. Mintz, "Media and museums: A museum perspective," in *The Virtual and the Real: Media in the Museum*, S. Thomas and A. Mintz, Eds. American Association of Museums, Washington DC, USA, pp. 19–34, 1998.

[21] H. Ogata, M. Li, B. Hou, N. Uosaki, M. El-Bishouty, and Y. Yano, "SCROLL: Supporting to share and reuse ubiquitous learning log in the context of language learning," *Res. Practice Technol. Enhanced Learning*, vol. 6, no. 2, pp. 69–82, 2011.

[22] S. G. Paris, "Situated motivation and informal learning," *J. Museum Edu.*, vol. 22, no. 2/3, pp. 22–27, 1997.

[23] R. Reynolds, K. Walker, and C. Speight, "Web based museum trails on PDAs for university-level design students: Design and evaluation," *Comput. Edu.*, vol. 55, no. 3, pp. 994–1003, 2010.

[24] O. Sagy, Y. Kali, M. Tsaushu, T. Tal, D. Zilberstein, and S. Gepstein, "Promoting a culture of learning that is based on internal values in an introductory undergraduate level biology course," paper presented at the 14th Biennial European Association for Research on Learning and Instruction Conf., Exeter, U.K., 2011, pp. 70–77 [Online]. Available: http://www.openu.ac.il/innovation/chais2012/downloads/k-Sagy-etal-88_eng.pdf

[25] G. Salomon and D. N. Perkins, "Individual and social aspects of learning," *Rev. Res. Edu.*, vol. 23, pp. 1–24, 1998.

[26] W. Sandoval, "Conjecture mapping: An approach to systematic educational design research," *J. Learning Sci.*, vol. 23, no. 1, pp. 18–36, 2014.

[27] R. Semper and M. Spasojevic, "The electronic guidebook: Using portable devices and a wireless web-based network to extend the museum experience," in *Proc. Museums Web*, Apr. 2002, [Online]. Available: http://www.museumsandtheweb.com/mw2002/papers/semper/semper.html

[28] M. Sharples, I. Amedillo Sanchez, M. Milrad, and G. Vavoula, "Mobile learning: Small devices, big issues," in *Technology Enhanced Learning: Principles and Products*, N. Balacheff, S. Ludvigsen, T. Jong, and S. Barnes, Eds. Heidelberg, Germany: Springer, 2009, pp. 233–249.

[29] C. Speight, R. Reynolds, and K. Walker, "Bridging formal and informal learning using mobile digital museum trails," in *Proc. 3rd WLE Mobile Learning Symp.: Mobile Learning Cultures Across Edu., Work Leisure*, Mar. 2009, [Online]. Avilable: http://arts.brighton.ac.uk/__data/assets/pdf_file/0009/38367/wle_reynolds-speight-walker-2009.pdf

[30] Y. T. Sung, H. T. Hou, C. K. Liu, and K. E. Chang, "Mobile guide system using problem-solving strategy for museum learning: A sequential learning behavioral pattern analysis," *J. Comput. Assisted Learning*, vol. 26, no. 2, pp. 106–115, Apr. 2010.

[31] H. Y. Sung, G. I. Hwang, S. Y. Liu, and I. H. Chiu, "A prompt-based annotation approach to conducting mobile learning activities for architecture design courses," *Comput. Edu.*, vol. 76, pp. 80–90, 2014.

[32] L. Tallon and K. Walker, *Digital Technologies and the Museum Experience: Handheld Guides and Other Media*. Lanham, MD, USA: Alta Mira Press, 2008.

[33] G. Vavoula, M. Sharples, P. Rudman, J. Meek, and P. Lonsdale, "Myartspace: Design and evaluation of support for learning with multimedia phones between classrooms and museum," *Comput. Edu.*, vol. 53, no. 2, pp. 286–299, Sep. 2009.

[34] D. Wessel and E. Mayer, "Potentials and challenges of mobile media in museums," *Int. J. Interactive Mobile Technol.*, vol. 1, no. 1, pp. 1–8, 2007.

[35] N. Winters, "What is mobile learning?" in *Big Issues in Mobile Learning*, M. Sharples, Ed. Nottingham, U.K.: Kaleidoscope Network of Excellence, Mobile Learning Initiative, 2007, pp. 5–9.

[36] L. H. Wong and C. K. Looi, "What seams do we remove in mobile-assisted seamless learning? A critical review of the literature," *Comput. Edu.*, vol. 57, no. 4, pp. 2364–2381, 2011.

[37] K. Yatani, M. Onuma, M. Sugimoto, and F. Kusunoki, "Musex: A system for supporting children's collaborative learning in a museum with PDAs," *Syst. Comput. Japan*, vol. 35, no. 14, pp. 54–63, 2004.

Yael Kali is an associate professor of technology-enhanced learning, a director of the Learning In a NetworKed Society (LINKS) Israeli Center of Research Excellence (I-CORE), and head of the Technologies in Education Graduate Program, at the Faculty of Education, University of Haifa. She explores technology-enhanced learning and teaching at various levels, from junior high school to higher education. Her work focuses on the role of design principles for supporting Computer Supported Collaborative Learning. She has been a faculty member in the Department of Education in Technology and Science at the Technion—Israel Institute of Technology for seven years, and a co-principal investigator at the Technology Enhanced Learning in Science centre, headquartered at the University of California, Berkeley. She has also served as a visiting scholar at the Centre for Research on Computer Supported Learning & Cognition in the Faculty of Education and Social Work, University of Sydney. She currently serves as an associate editor for the journal *Instructional Science*.

Ornit Sagy received the BSc degree in computer science, the MBA degree in industrial engineering, and the PhD degree from the Department of Education in Technology and Science from the Technion—Israel Institute of Technology. She is a postdoctoral researcher in the Technologies in Education Graduate Program at the Faculty of Education, University of Haifa. Her expertise is in designing and exploring technology-enhanced learning environments to promote an internal-value-based learning culture. In addition to her 13 years of experience as a software engineer in the Israeli and American high-tech industry, she has taught computer science in high-schools, and graduate courses in technology-enhanced learning at the University of Haifa and the Weizmann Institute.

Tsvi Kuflik received the BSc, MSc, and PhD degrees from the Ben-Gurion University of the Negev in 1987, 1994, and 2004, respectively. He is an associate professor of information systems and the chair of the Information Systems Department at the University of Haifa, Israel. His main research interests are intelligent user interfaces, personalization in ubiquitous computing, and personalization in cultural heritage. He published more than 150 scientific papers and has been an organizer and PC member of numerous academic conferences and workshops. He is an ACM distinguished scientist, and is a senior member of the IEEE and IEEE Computer Society.

Orit Mogilevsky is a master's degree student in the Technologies in Education Graduate Program at the Faculty of Education, University of Haifa. During her research, she was also a visitors' guide at the Hecht museum. She works as computation consultant in higher education institutions.

Emma Maayan-Fanar received the PhD degree from the Hebrew University of Jerusalem in 2004. She is a senior lecturer at the Art History Department at the University of Haifa, Israel. Her main research interests are Byzantine illuminated manuscripts, Early Christian and Jewish art in the Holy Land, and the 19th century photography of the Holy Land. She published a book *Revelation through the Alphabet: Aniconism and Illuminated Initial Letters in Byzantine Artistic Imagination*, Geneve: La Pomme d'Or, 2011 and a number of articles in peer-reviewed journals.