



Enhancing 21st Century Skills with AR: Using the Gradual Immersion Method to develop Collaborative Creativity

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Received 19 March 2016 • Revised 16 July 2016 • Accepted 22 August 2016

ABSTRACT

As 21st century skills (e.g., creativity and collaboration) are informally developed by tech-savvy learners in the Digital Age, technology-based strategies to develop such skills in non-formal and formal contexts are necessary to reduce the gap between academic and business organizations on the one hand, and the revolutionary wave of self-taught networked learners on the other. In light of this, the Gradual Immersion Method (GIM) was designed to enhance collaborative creativity using interactive devices and augmented reality (AR), to support creativity-based learning, such as in the integrated study of Science, Technology, Engineering, Arts and Mathematics (STEAM). The GIM consists of three intuitive modules wherein learners collaboratively achieve learning object goals through interaction with images and 3D models, in a sequential transition from 2D to 3D and then to AR. In this paper, the process is illustrated through the deployment of the GIM in the study of Surrealist art features, using the Art Movement Learning App (AMLA), an area-specific technological solution based on the GIM, designed as foundation architecture for the investigation of a wide range of topics in an interactive manner.

Keywords: 21st Century Skills, AMLA, AR, Creativity, GIM, STEAM

INTRODUCTION

The increasing call for a culture of innovation, driven by technological shifts in industry, necessitates the development of 21st century skills which promote creative thinking and teamwork in educational and business settings, and facilitate the creation of new knowledge (Pacific Policy Research Center, 2010). Creativity and collaboration, both developable skills of great value in the pursuit of these goals, are typically observed in arts education, where the design process and creative process are commonly employed in what industry terms design

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State of the literature

- The new culture of innovation demands the development of 21st century skills which promote creative thinking and teamwork in educational and business settings.
- Technological tools such as Augmented Reality (AR) are making it easier for users to autonomously produce flexible learning and/or entertainment-based software and hardware which reflect the dynamism of their personality.
- There is ever-increasing demand for technology-based methods to support learning and guide users to filter and acquire relevant knowledge according to the present and future academic and business demands.

Contribution of this paper to the literature

- This paper investigates the features and potentialities of the Gradual Immersion Method (GIM) as a strategic cognitive-pedagogical approach that promotes intuitive learning through digital creation, using interactive devices and 2D, 3D and AR activities.
- A GIM-based application called the Art Movement Learning App (AMLA) was developed, which facilitates intuitive collaborative performance of tasks using interactive devices and AR.
- The GIM enhances creativity, collaboration, and other relevant 21st century skills that aid performance in formal academic, as well as in non-formal environments.

thinking; that is, solving problems to achieve a given outcome (e.g., software, products, advertisements). However, these features of design are also increasingly being considered relevant for interdisciplinary work which demands problem solving and the search for alternative solutions in a broadly aesthetic context, as clearly represented in STEAM (Science, Technology, Engineering, Arts and Mathematics) studies, a far-reaching academic proposal which embraces methods typical of the creative arts, in order to enhance science education (Bequette & Bequette, 2012).

At the same time, there is ever-increasing demand for technology-based methods to support learning. With the technological empowerment of new generations of learners using Apps in mobile interactive devices, and the development of augmented reality (AR) systems that combine real and digital worlds, the gap between traditional teaching methods in formal academic institutions and alternative autonomous learning has grown, accelerated by the rapid development of new applications, many designed by users themselves. On the other hand, these same conditions are highly conducive to informal and non-formal learning, acquired through experience outside the traditional academic settings, such as family, interest-based communities, or the workplace, contributing to skills development which can be identified, and can give rise or contribute to qualifications through accreditation or validation processes (UNESCO, 2012). However, in attempting to enrich learning experiences that foster development of 21st century skills in educational contexts, the threat of information overload calls for innovative technology-based methods and strategies which guide users to filter and acquire relevant knowledge according to the present and future academic and business demands.

Against this background, we here describe the salient features and potentialities of the Gradual Immersion Method (GIM), a strategic cognitive-pedagogical approach that promotes intuitive learning through digital creation, using interactive devices and 2D, 3D and AR activities. The GIM enhances creativity, collaboration, and other relevant 21st century skills that aid performance in non-formal environments such as are found in museums, community entrepreneurial groups and other organizations, as well as in formal academic contexts such as STEAM.

The structure of the article is as follows. Section 1 provides an analysis of the role of creative skills and AR technology in relation to 21st century educational demands. Section 2 introduces the research methodology, and then details both the GIM and the Art Movement Learning App (AMLA), a software architecture specially designed for a GIM-based case study involving the pedagogical introduction to Surrealism and other art movements. Section 3 summarizes the case study, and Section 4 presents the main conclusions of the article.

21st century skills in education

Based on the current demands of the information- and knowledge-based global society of the Digital Age, the practices and expectations of educational and working environments have been analyzed by educators and policy makers to identify and define the 21st century skills which are required for citizens to thrive in this era of rapid transformation. Though still in the process of being fully articulated, several frameworks for such 21st century skills have been released and are in ongoing revision.

Two well-known studies investigate the specific roles of creativity and collaboration (among other skills) in present and future education. A comprehensive study by NCREL and the Metiri Group (2003), focusing on sources such as literature reviews, industry reports, workforce trends, and data from educators, identified four clusters of skill sets, constituting the so called enGauge 21st Century Skills: digital-age literacy, inventive thinking, effective communication, and high productivity. The inventive-thinking cluster, characterized by higher-level cognitive skills critical to thriving in the Digital Age, includes the concept of creativity, which is defined as “The act of bringing something into existence that is genuinely new and original, whether personally (original only to the individual) or culturally (where the work adds significantly to a domain of culture as recognized by experts)” (NCREL & Metiri Group, 2003). The concept of collaboration is discussed as part of ‘Teaming and collaboration’ in the effective-communication cluster, wherein the study stresses the importance of managing the usage of information technologies with awareness of their impact on society; the concept is defined as “Cooperative interaction between two or more individuals working together to solve problems, create novel products, or learn and master content” (NCREL & Metiri Group, 2003).

The second study, structured as a collective vision of the skills, knowledge, and expertise necessary for learners to generally succeed in contemporary work and life, is the ‘Framework for 21st Century Learning’, developed by the Partnership for 21st Century Learning (2007)

with various inputs from educational and business sources. The framework is divided into a number of '21st Century Student Outcomes', including: key subjects and 21st century themes; learning and innovation skills; information, media and technology skills; and life and career skills. Learning and innovation skills distinguish learners who are ready to face complex life and work experiences from those who are not. These skills include: creativity and innovation; critical thinking and problem solving; communication; and collaboration. In addition, the framework identifies a number of '21st Century Support Systems' aimed at making the learning experience relevant, engaging, and personalized (Partnership for 21st Century Learning, 2007).

Regarding the connection between education and business in the Digital Age, Ken Kay, founder of the 'Partnership for 21st Century Learning', notes that: "A 21st century education must be tied to outcomes, in terms of proficiency in core subject knowledge and 21st century skills that are expected and highly valued in school, work, and community settings" (Bellanca & Brandt, 2010). In this demanding context, creativity and collaboration stand out for their great importance in the process of active learning, and thus together formed the primary focus for this study.

Creativity in education

Creative skills are considered relevant when applied in a specific context, for example in the engineering of a machine, the formulation of a chemical model, or the digital creation of an artwork. From the researcher's perspective, creativity and education typically overlap when relying on insight to solve problems, innovating the teaching-learning process, and seeking to enhance learners' creativity (Smith & Smith, 2010); all of which are recurring themes in efforts to enhance creativity in STEAM studies (Connor, Karmokar, Whittington, & Walker, 2014; Guyotte et al., 2015).

From a creative cognition perspective, creativity can be enhanced by quasi-perceptual experiences based on mental processes such as the generation of visual imagery, which may be useful in enhancing learners' creative skills for the invention or engineering of innovative outcomes (Finke, Ward, & Smith, 1992). One such process is *bisociation*, the deliberate combination of two elements or thoughts (such as objects or words) with no obvious relationship, which increases the likelihood of generating innovative outcomes (Koestler, 1964). Thus, by identifying and properly deploying specific cognitive techniques for enhancing creativity in education, problems may be solved, innovative products designed, and artistic expressions produced (Baughman & Mumford, 1995; Wisniewski & Love, 1998). However, a meta-study by Kowaltowski (2009) concerning methods for stimulating creativity, including mental maps, focus groups, and brainstorming, concluded that, though a variety of such approaches are used in the educational contexts of the arts and engineering design for example, teachers may not know whether the means employed in their courses are methods, techniques, or tools. This suggests that, when proposing such creativity enhancing approaches, especially if technology-based, it is desirable to properly define the relevant

objectives, characteristics, and even mental processes involved, as well as to describe the relevant contexts for application.

Augmented Reality (AR) in education

In the 21st century, the role of the learner has undergone a paradigm shift in which he/she is conceived as a transformer rather than just a receiver of information. Current technological tools have empowered young users, making it easier for them to autonomously produce flexible learning and/or entertainment-based software and hardware which reflect the dynamism of their personality. At the same time, the increasing diversity among learners, in the manner of perceiving the world through interactive digital displays, has resulted in a boom in digital education, which has been accompanied by burgeoning growth in electronic, mobile, blended, home, and other forms of learning; all of which demands constant renewal of the skills and approaches of those providing learning experiences in education. Interacting with digital displays, learners explore compelling, imaginative, and self-paced practical experiences which disrupt traditional systematic patterns for generating knowledge and skills. Meanwhile, with its simplicity, portability, and wide application, augmented reality (AR) has positioned itself as a valuable tool for enhancing traditional curricula and learning techniques. Ideally, AR systems enable the incorporation of 3D digital elements in the real world, providing interaction in real time and enriching the perceived information, with the utopian aim of a fully 'Mixed Reality', the seamless integration of the real and digital worlds (Milgram & Kishino, 1994; Azuma, 1997).

AR has typically been applied in education as a means to introduce abstract, difficult to assimilate, dangerous, and/or conventionally inaccessible information and experience. More specifically, in terms of the development of creative skills, it is proving to be a useful tool, with great promise for the future development of learning (Bower, 2014). Typical AR deployments range from collaborative tools for promoting autonomous learning in engineering labs (Martin-Gutierrez, Fabiani, Benesova, Meneses, & Mora, 2015), to enhancing learning in mathematics (Coimbra, Cardoso, & Mateus, 2015), and supporting the study of computer science using mobile devices (Kose, Koc, & Yucesoy, 2013).

AR applications are unquestionably desirable for strengthening the aforementioned 21st century skills involved in STEAM studies, for example (Muschio, Zhu, & Foster, 2015), but it is imperative for any such application to be governed by pedagogical methods aimed at supporting the development of such skills.

METHODOLOGY

This is a theoretical study whose aim is to present a method, along with related technological support, to enhance creativity and collaboration in the learning process. The method employs AR technology, with a focus on non-formal learning, and an eye to assisting learners in STEAM studies and other formal and informal contexts.

The Gradual Immersion Method (GIM)

In response to the need for guidelines to enhance creativity and collaboration in technological and educational contexts, Sanabria (2015) proposed the Gradual Immersion Method (GIM), a cognitive-pedagogical approach that encourages intuitive learning using digital interactive devices and AR. The method is composed of three modules which, as its name suggests, enable learners' gradual immersion in two complementary respects: facilitating the interactive appropriation of target knowledge, and guiding their perception through increasingly complex spatial dimensions, toward Mixed Reality. The development of creative skills, together with the acquisition of knowledge on a selected topic, is facilitated by means of reusable instructional components known as learning objects (LOs): digital information structures supporting education or training, ideally integrated as a set of computer-based instructions, goals, learning tasks, and assessment instruments (Wiley, 2000). In the GIM, the LOs focus on challenging tasks involving interactive devices, carried out collaboratively by teams of 4-5 learners, and assessed at the end of a given LO (phase) or set of LOs (module), by the learners themselves, their peers, the researchers, and/or the audience. Examples of GIM-based LOs include combining two images to create a third with unexpected features, and identifying the common characteristics of a diverse group of images; always encouraging learners to appropriate target knowledge through collaborative interaction.

With respect to the progress through spatial dimensions, the GIM guides learners through LOs on digital interactive displays, with activities performed in 2D, 3D, and finally AR, which gradually immerses them in a Mixed Reality experience. This process takes place at the interface, where the LOs present different challenges based on the following sequence: interacting with flat images (2D); working with volume on 3D models (3D); and combining digital elements (in 2D and 3D) with real-world elements (AR).

The essence of the GIM is the creative process which iterates through generative and exploratory cognitive cycles, based on three modules (**Figure 1**) which guide the learners from familiarization with key features of a given topic, to digital creation using AR, and finally to the exhibition of products of their learning experience. The three modules are divided into phases with specific goals that together support the objective of the respective module, and enable spatial transition from 2D to 3D, and then to AR.

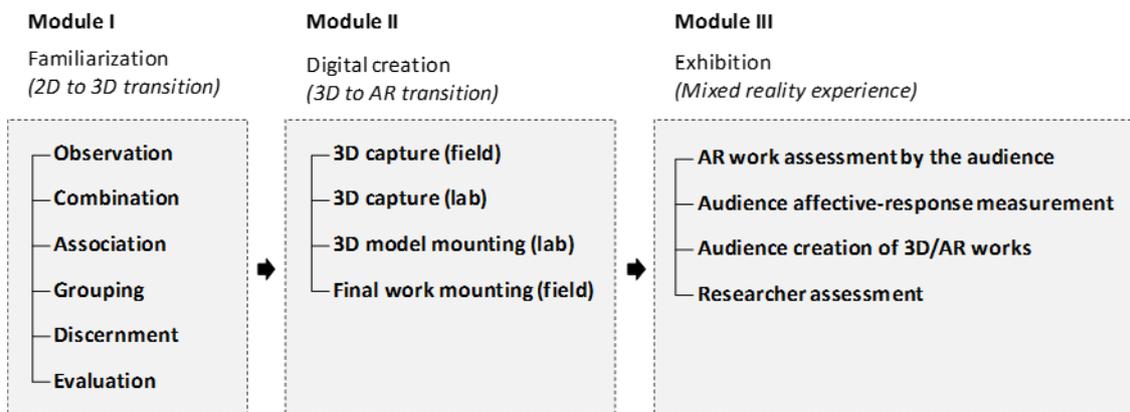


Figure 1. The three GIM modules (Sanabria, 2015)

The first module aims at familiarizing teams of learners with a specific topic, in six phases (Figure 2). (1) Observation: a series of images are displayed, and a list of common features (or ‘criteria’) is generated by each team. (2) Combination: provided with a number of images (e.g., people, objects, animals), teams create original combinations based on the criteria generated in Phase 1; the process is then repeated with 3D models. (3) Association: a primary image is displayed, surrounded by its key elements, and teams assign these elements to their original positions in the image. (4) Grouping: a series of images are categorized based on their common characteristics, collaboratively identified by each team. (5) Discernment: pairs of images are displayed, and teams choose the one that most accurately corresponds to the criteria and characteristics defined in the previous phases. (6) Evaluation: combinations created in 2D and 3D in Phase 2 are evaluated by other teams; for instance, using an embedded affective or creativity scale. Depending on the objective, evaluation may be scheduled for earlier or later in the overall process (i.e., from the first to the fourth degree of intuition-sensitive peer evaluation).

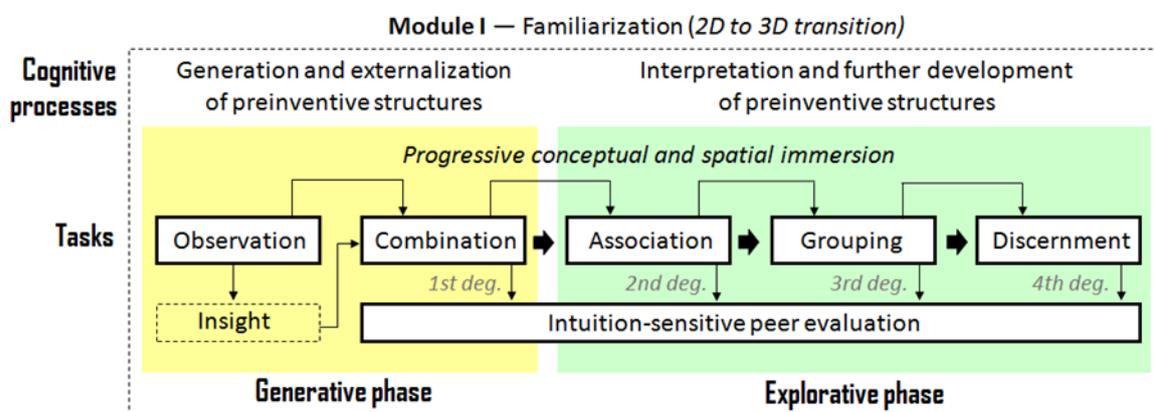


Figure 2. Module I: Six phases of the GIM on interactive surfaces (Sanabria, 2015)

The second module consists of a single generative phase involving an iterative transition process, dedicated to the digital creation of an AR product based on 3D models (Figure 3). After working through a creative process of visualizing and articulating a combination of objects through capturing and combining 3D models, the team generates, regenerates, or modifies its preventive structures. These structures are externalized through the creation of an AR product which combines a real object (originally captured in the field) and a digital object (originally captured or designed in the lab).

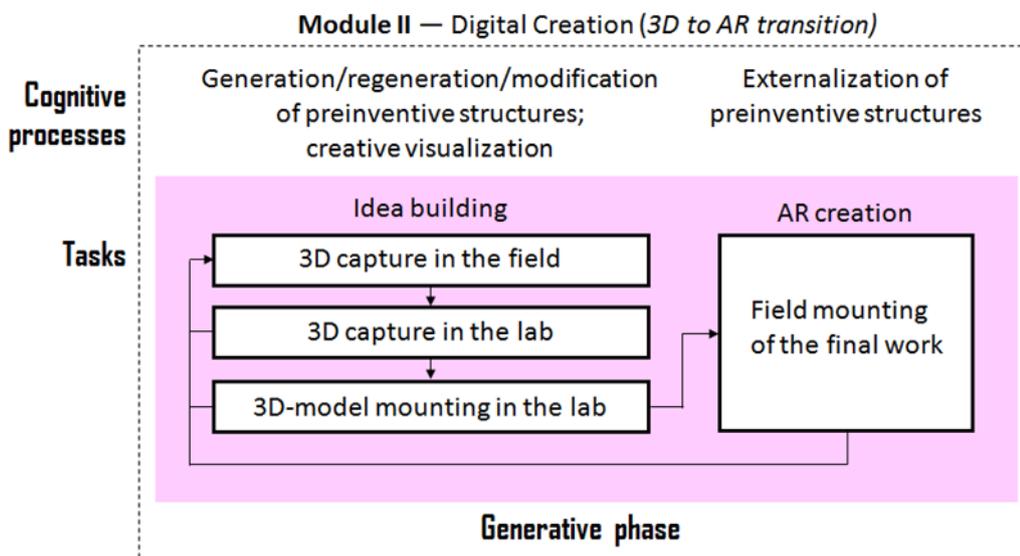


Figure 3. Module II: AR generative phase on mobile devices (Sanabria, 2015)

The third module completes the GIM process, with the exhibition of an AR product (Figure 4). The act of displaying products (exploratory phase) offers learners a chance to interpret their own externalized preinventive structures, and at the same time enables an audience to provide feedback, which can be measured through their affective reactions for example. If desired, audience members may also be provided with a digital interface where they can create their own 3D/AR products, reproducing a synthesized version of the observed exhibition. Meanwhile, for the facilitator or researcher, audience data, in the form of feedback, reaction, and/or the 3D/AR creation process, enables assessment of the learners' experience, and specifically, how well the respective LOs were incorporated and expressed by each team's AR product and assimilated by the audience.

To illustrate the deployment of the GIM in non-formal learning, a contextualized case involving the study of art movements is presented below. The section also describes the software application which was specifically designed to support the three modules above, as well as its architectural base, which can be easily adapted to support STEAM studies.

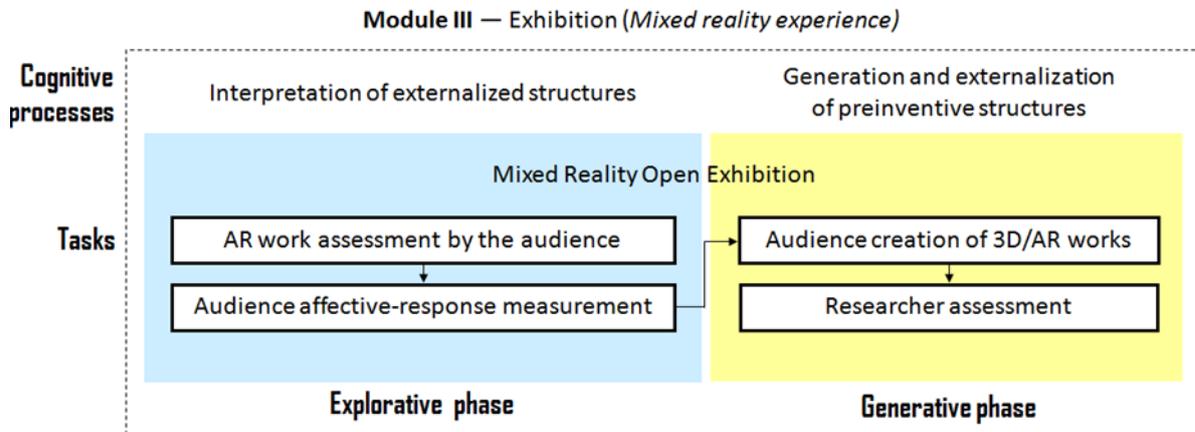


Figure 4. Module III: AR public exhibition on mobile devices (Sanabria, 2015)

Software developed for the GIM

To support the learning of art movements (e.g., Surrealism, Cubism, Impressionism), Arámburo-Lizárraga & Sanabria (2015) proposed a GIM-based application called the Art Movement Learning App (AMLA), which facilitates intuitive collaborative performance of tasks using interactive devices and AR. The AMLA consists of two modules: (1) familiarization (based on the GIM's Module I), which introduces key features of a chosen art movement, in six phases involving interactive LOs, including inter-participant evaluation; and (2) an AR module (based on the GIM's Modules II and III), which guides learners through the generation of a digital creative product, and then the mounting of this product in a real-world environment, using AR with GPS coordinates, known as AR Level 2 (Lens-Fitzgerald, 2009).

In order to provide LOs for interactive whiteboards (IWBs) and mobile devices, aimed at exploring features of different art movements, the Unity3D multiplatform game engine (Unity, 2016) was chosen as an ideal framework for developing the AMLA. The AMLA's architecture is based on four concepts corresponding to Unity3D elements: (1) assets, (2) GameObjects, (3) scenes, and (4) scripts; which were adapted as follows:

- 1) Assets: supporting files to create and configure LOs; for example, artworks (2D images), instructions (text), or animals, objects, and people (3D objects).
- 2) GameObjects: containers that enable the configuration of objects on the screen; for example, a horizontal reel displaying a set of artworks or interface elements (text, icons, buttons, etc.).
- 3) Scenes: structures containing the GameObjects, to direct their functionality toward a given objective; for example, each of the six phases of the GIM (observation, combination, etc.) is presented as a scene.

4) Scripts: programmed code providing interactivity among Scenes and GameObjects; for example, transitions between GIM phases, or validating input devices (e.g., keyboard, mouse, touch screen).

Just as the AMLA can be easily adapted for teaching art movements, the simple modification of its assets enables effective STEAM studies benefitting from creative capability, such as exploring chemical bonding, eliciting bisociated (disruptive) industrial design, or imaginative innovation of engineering structures. In terms of the 21st century skills frameworks, the AMLA aids in the development of technological skills with regard to creating, evaluating, and interacting with digital forms of information, using digital devices. Overall, this interactive technology encourages collaborative creativity in accomplishing LOs.

Figure 5 shows how the three GIM modules align with the two AMLA modules, and illustrates the respective processes involved in each phase, to achieve the respective objectives. For example, for the observation phase of Module I, aimed at familiarizing learners with some characteristic of the chosen art movement (e.g., use of color, contrast, or technique), three processes are required: (a) ‘Browse within the reel’ enables the display of artworks and user navigation between images; (b) ‘Load images’ enables the incorporation of 2D images (assets) from the directory to the reel; and (c) ‘Display images in a horizontal reel’ enables users to select and zoom-in on images so that their key characteristics can be observed in detail.

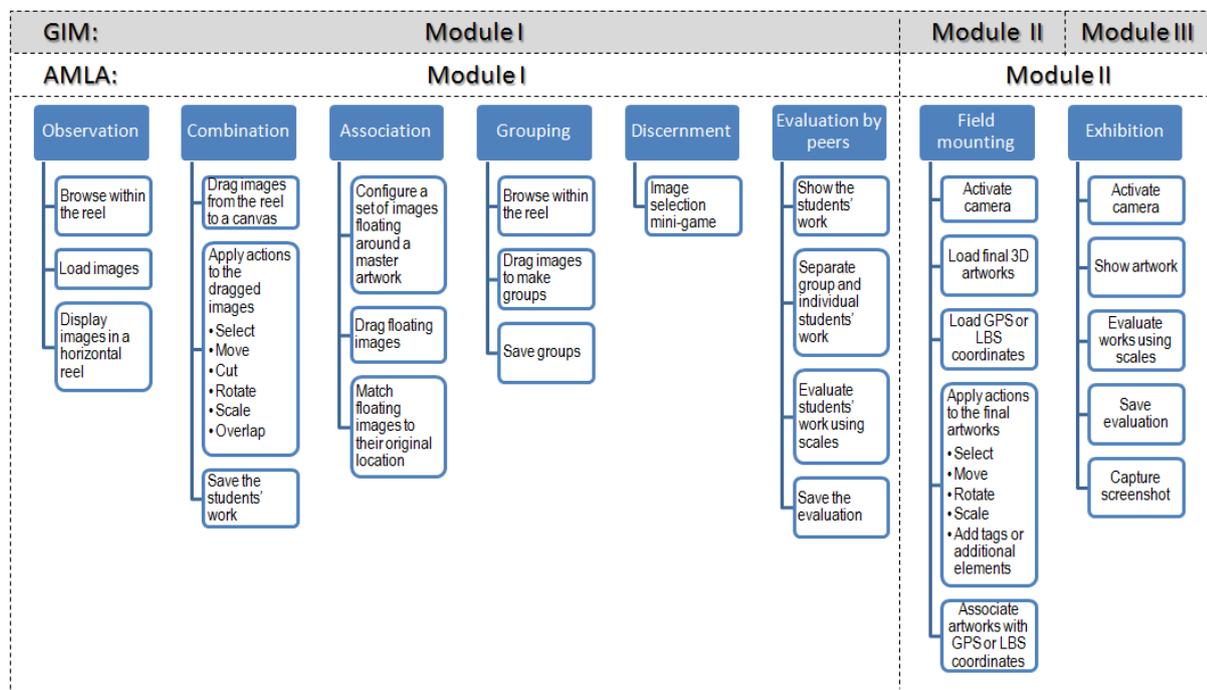


Figure 5. AMLA processes structured as a technological application for the GIM (Arámuburo-Lizárraga & Sanabria, 2015)

DEPLOYMENT OF THE GIM IN A CASE STUDY

One of the distinctive features of the GIM is its iterative process for stimulating learners' creativity in a bisociated or disruptive manner, aimed at facilitating the gestation of ideas, the development of creative products, and the conception or improvement of relevant processes. This feature has great affinity with STEAM studies, especially when focused on the arts, encouraging critical thinking and problem solving which reflects on how learners synthesize, analyze and interpret information through a collaborative process of critical reflection resulting in a creative experience. In a non-formal educational case study on the implementation of the GIM, senior high school students were taught to recognize and appropriate the characteristics of the Surrealist art movement (Sanabria et al., 2015). The AMLA modules were adapted from the GIM modules, to illustrate various bisociated characteristics of Surrealist artworks as a source of insight and elicitation of ideas.

Module I of the GIM, 'Familiarization' (Figure 2), was adapted for the AMLA interface, to guide participants through the module's six phases and their corresponding goals for each LO (Figure 6).

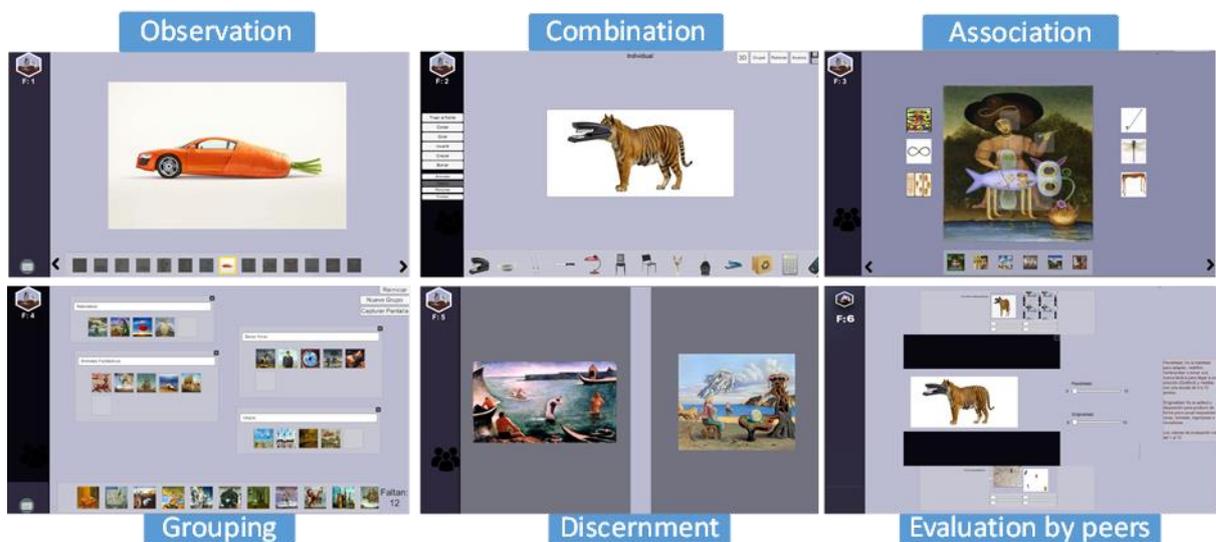


Figure 6. Six interface screens from Module I of the GIM, as applied to Surrealist art study*

*Primary works, by module: In Observation, Hasbro Inc. (Scrabble)©; In Association, 'The Surrealist' by V. Brauner; In Discernment, (left) 'Nuotatori' by C. Dalmazzo; (right) 'La Playa está Desierta y Solitaria' by A. Planells.

For creative AR production in Modules II and III of the GIM, specifically for the 'Field mounting' phase, an interface for mobile devices was developed and deployed (Figure 7). The interface enabled the anchoring of a 3D model in the physical environment, using GPS coordinates, and adjustment of perspective on the object, using the tools provided (e.g., scale, rotate, move).

For creative AR production in Modules II and III of the GIM, specifically for the 'Field mounting' phase, an interface for mobile devices was developed and deployed (Figure 7). The interface enabled the anchoring of a 3D model in the physical environment, using GPS coordinates, and adjustment of perspective on the object, using the tools provided (e.g., scale, rotate, move).

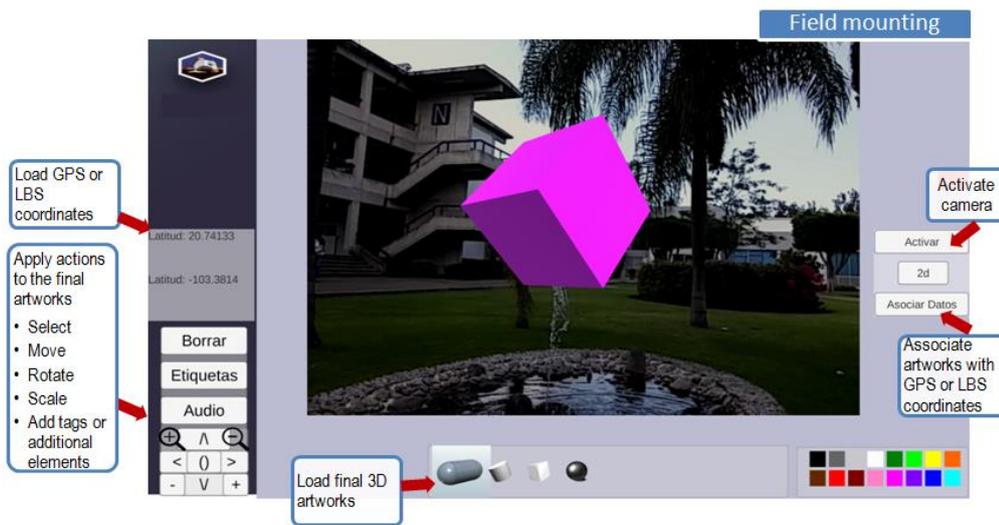


Figure 7. Processes and components of AMLA Module II - Phase 1 (Arámuburo-Lizárraga & Sanabria, 2015)

The deployment of the GIM and AMLA for the study of the Surrealist art movement showed the potential of the method to develop and promote the aforementioned 21st century skills, in particular creativity and collaboration, in the context of non-formal learning. Figure 8 shows the GIM 3 Modules in action: (left) learner teams interact with the AMLA as they familiarize themselves with Surrealist art features (Module I); (center) teams create an AR experience, using mobile devices to anchor a 3D model in the physical environment (Module II); (right) the resulting AR combination is displayed on a mobile device with the AMLA's viewer interface (Module III).



Figure 8. GIM and AMLA deployment for the study of Surrealism.

CONCLUSION

The key components of the GIM and AMLA, as illustrated in the case study, enable this cognitive and pedagogical approach to effectively address the needs of learning strategies aimed at fostering 21st century skills; focusing on creativity and collaboration, encouraging critical thinking, and enhancing the problem solving process through critical reflection involved in the creative experience. In turn, such skills may support STEAM studies by eliciting bisociated thinking for such purposes as generating ideas or solving problems in formal, non-formal, and informal learning.

The technological software solution represented by the AMLA satisfies the GIM's requirements for flexibility, which allow for easy adaptability in developing LOs for the integrated studies of STEAM. The AMLA employs digital technologies that encourage the creative organization, communication, and management of information, in order to solve tasks or problems related to the development of key 21st century skills. In addition, the AMLA can be used on a variety of different hardware and software platforms, depending on the needs of the project.

Deployment of the GIM at the senior high school level resulted in enhanced learner performance in terms of creativity and collaborative work, demonstrated through effective and respectful interaction among teams when using interactive devices. The project's scope of application can be easily extended to include real-life contexts such as the design of digital and industrial products or original solutions which are relevant in the economy of innovation. In addition, the modules and phases (LOs) of the GIM may be used independently for generating novel ideas in varied environments such as corporations, museums, training workshops, and classrooms.

ACKNOWLEDGEMENTS

This research was supported by a postdoctoral research grant for 2014-2015 from the Mexican National Council for Science and Technology (CONACYT). The authors would like to thank the following sponsors: the ATI-Center of Experiences, which provided equipment and space to perform the experiment; the Instituto Cultural Cabañas museum, which provided gallery space in which to conduct the experiment; the MUSA art museum, which offered professional insight into Surrealist art; the school administrators of Escuela Preparatoria No.7 of the Universidad de Guadalajara, Centro De Enseñanza Técnica Industrial (CETI) Colomos, and Centro de Educación Artística (CEDART) 'José Clemente Orozco', who provided the student participants for the project; and finally, the facilitators from the Masters in Learning Technologies (MTA) from the Universidad de Guadalajara for their general assistance in the study.

REFERENCES

- Arámuburo-Lizárraga, J. & Sanabria, J. C. (2015). An application for the study of art movements. *Procedia Computer Science*, 75, 34–42. doi:10.1016/j.procs.2015.12.196
- Azuma, R. (1997). A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments*, 6(4), 355-385.
- Baughman, W. A. & Mumford, M.D. (1995). Process-analytic models of creative capacities: Operations influencing the combination and reorganization processes. *Creativity Research Journal*, 8, 37–62.
- Bellanca, J. A., & Brandt, R. S. (2010). *21st century skills: Rethinking how students learn*. Bloomington, IN: Solution Tree Press.
- Bequette, J. W., & Bequette M. B. (2012). A place for art and design education in the STEM conversation, *Art Education*, 65(2), 40-47. doi: 10.1080/00043125.2012.11519167
- Bower M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented Reality in education - cases, places and potentials. *Educational Media International*, 51(1), 1-15. doi: 10.1109/CICEM.2013.6820176
- Coimbra, T., Cardoso, T., & Mateus, A. (2015). Augmented Reality: an enhancer for higher education students in math's learning? *Proceedings of the 6th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion*, 67, 332-339. doi:10.1016/j.procs.2015.09.277
- Connor, A., Karmokar, S., Whittington, C., & Walker, C. (2014). Full STEAM ahead: a manifesto for integrating arts pedagogics into STEM education. *International Conference on Year Teaching, Assessment and Learning (TALE)*, 319 - 326. doi: 10.1109/TALE.2014.7062556
- Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications*, Cambridge, MA: MIT Press.
- Guyotte, K. W., Sochacka, N. W., Costantino, T. E., Kellam, N., Kellam, N. N., & Walther, J. (2015). Collaborative creativity in STEAM: Narratives of art education students' experiences in transdisciplinary spaces. *International Journal of Education & the Arts*, 16(15). Retrieved from <http://www.ijea.org/v16n15/>
- Koestler, A. (1964). *The act of creation*. New York: Macmillan.
- Kose, U., Koc, D., & Yucesoy, S.A. (2013). An Augmented Reality based mobile software to support learning experiences in computer science courses, 2013 International Conference on Virtual and Augmented Reality in Education, *Procedia Computer Science*, 25, 370–374. doi:10.1016/j.procs.2013.11.045
- Kowaltowski, D., Bianchi, G., & de Pavia, V. (2010). Methods that may stimulate creativity and their use in architectural design education, *International Journal of Technology and Design Education*, 20, 453-476.
- Lens-Fitzgerald, M. (2009). Augmented Reality Hype Cycle. Retrieved from <http://www.sprxmobile.com/the-augmented-reality-hype-cycle/>.
- Martin-Gutierrez, J., Fabiani, P., Benesova, W., Meneses-Fernandez, M.D., & Mora C.E. (2015), Augmented reality to promote collaborative and autonomous learning in higher education. *Computers in Human Behavior*. 51, 752–761. doi:10.1016/j.chb.2014.11.093
- Milgram, P., & Kishino, F. (1994). A taxonomy of Mixed Reality visual displays. *IEICE Trans. Information and Systems*, E77-D(12), 1321-1329.
- Muschio, G., Zhu, J., & Foster, A. (2015). Revitalizing Peale's Museum as a digital interactive learning environment. *Digital Heritage*. 2, 683 - 686, doi: 10.1109/DigitalHeritage.2015.7419598

- NCREL & Metiri Group. (2003). enGauge 21st century skills: Literacy in the digital age. Retrieved from <http://pict.sdsu.edu/engauge21st.pdf>
- Pacific Policy Research Center. (2010). 21st century skills for students and teachers. Honolulu: Kamehameha Schools, Research & Evaluation Division. Retrieved from http://www.ksbe.edu/_assets/spi/pdfs/21_century_skills_full.pdf
- Partnership for 21st Century Learning. (2007). Framework for 21st century learning. Retrieved from http://www.p21.org/storage/documents/docs/P21_Framework_Definitions_New_Logo_2015.pdf
- Sanabria, J.C. (2015). The Gradual Immersion Method (GIM): Pedagogical Transformation into Mixed Reality. *Procedia Computer Science*, 75, 369–374. doi:10.1016/j.procs.2015.12.259
- Sanabria, J.C., Chan, M.E., Mateos, L.R., Mariscal, J.L., Arámburo-Lizárraga, J., & De la Cruz, G. (2015) Applying the Gradual Immersion Method to Surrealist art creation using interactive whiteboards (IWBs), *International Journal of Arts & Sciences*, 8(06), 627–638.
- Smith, J.K, & Smith, L.F. (2010). Educational creativity. In Kaufman, J., and Sternberg, R., *The Cambridge Handbook of Creativity* (250-264). Cambridge University Press, New York. Chapter doi: <http://dx.doi.org/10.1017/CBO9780511763205.016>
- UNESCO Institute for Lifelong Learning (2012). *UNESCO Guidelines for the Recognition, Validation and Accreditation of the Outcomes of Nonformal and Informal Learning*. UIL, Germany. Retrieved from <http://unesdoc.unesco.org/images/0021/002163/216360e.pdf>
- Unity (2016). Retrieved from <https://unity3d.com/unity>
- Wiley, D.A. (2000). Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy. In D.A. Wiley (Ed.). *The Instructional Use of Learning Objects* [on-line]. Retrieved from <http://reusability.org/read/>
- Wisniewski, E.J., & Love, B.C. (1998). Relations versus properties in conceptual combination. *Journal of Memory and Language*, 38, 177-202.

<http://iserjournals.com/journals/eurasia>