ГЛАСНИК Српског географског друштва 102(1) 131-140
BULLETIN OF THE SERBIAN GEOGRAPHICAL SOCIETY 2022

Original scientific paper
UDC 004.922:930.85
https://doi.org/10.2298/GSGD2201131D

Received: March 30, 2022
Corrected: April 12, 2022
Accepted: April 25, 2022

Yulia Yu. Dyulicheva*, Dmitriy G. Malakhatko*, Raša Mladenović[1]**

** V. I. Vernadsky Crimean Federal University, Simferopol, Crimea, Russia*
*** University of Kragujevac, Faculty of Medical Science, Kragujevac, Serbia*

THE AUGMENTED REALITY USAGE FOR LEARNING OF DISAPPEARING HISTORICAL MONUMENTS

Abstract: The study is devoted to the development of a mobile application for the reconstruction in augmented reality of disappearing objects of cultural and historical heritage on the example of the Monzhene's castle, also known as the Kessler's estate. The importance of creating an archive of such digital twins - 3D-models for objects of cultural heritage that have been practically destroyed to the ground, the reconstruction of which is difficult, as well as for preserving the history and culture of ancestors, is noted. The effectiveness of using the developed application based on augmented reality technology in the educational process is confirmed by the results of a survey of 17 schoolchildren who used the application in the lessons of the history of their native land.

Key words: augmented reality, disappearing historical monuments, 3D-models, digital twins

[1] rasa.mladenovic@med.pr.ac.rs (corresponding author)

Introduction

One of the main purposes of AR/VR/MR technologies introduction in education are the improvement of students' involvement in learning process, the revitalization of educational content and the possibility of the interactive interaction and observation of the object of study, including the visualization of complex abstract concepts. The immersive technologies are becoming part of smart education, implementing the most important principles for ensuring the flexibility of learning in the interactive educational environments and free access to educational content around the world through the use of the augmented and virtual reality applications (Martí´n et al., 2019). Many researchers note the positive effect of the introduction of the immersive technologies in education such as improvement of collaboration between students, deep-diving into the topic of study, presentation of the learning materials in a diverting way, engaging in learning environments, exploring the possibilities of new innovative technologies, developing of the useful skills with the help of the simulation of physical processes and real conditions of the professional environments, etc. (Dyulicheva, 2020; Buboc et al., 2021; Sung et al., 2021; Vairinhos et al., 2021).

AR/VR/MR-technologies find more and more applications in education. For example, the amazing professional virtual environment with interactive virtual tools for future dentists (Dyulicheva et al., 2021), the awesome application for learning of the magnetic fields properties and the research of the micro-worlds for understanding the structure of substances (Cai et al., 2014; Liu et al., 2019), the interesting approach for understanding the main concepts of probability (Cai et al., 2020), the entertaining games with augmented reality for educational purposes (Rahmawati et al., 2022).

The knowledge of history contributes to patriotic education, understanding the significance of historical events and their influence on the formation and development of modern states. When studying history, students often experience difficulties associated with mess that occurs when remembering of more historical dates and historical events, lack of attention and time for memorization, as well as monotony and sameness of the presentation of the educational material (Chong & Yeo, 2016).

Through the introduction of immersive technologies, historical education is being transformed into a technique of captivating storytelling, which allows expanding horizons and imagination through immersion in the reconstruction of historical events in AR/VR/MR environments. Challenor and Ma (2019) note the effectiveness of the use of augmented reality applications for the formation of emotional perception of historical events, improving of students' academic performance, however, the studies on the development of long-term memories using augmented reality are insufficient (Challenor & Ma, 2019). The use of augmented reality in the study of history contributes to greater opportunities for choosing of styles and teaching methods, as well as increasing of the entertainment of the history course for younger pupils (Dirgantoro, 2021).

Overview of AR/VR/MR Technologies Usage in the History Education and Tourists' Tours

The most important application of the augmented reality in the education and tourism is the reconstruction of buildings and historical events. It is difficult for the stu-

dents to imagine what objects or clothes looked like in antiquity, what the buildings and cities were in the past, etc. The augmented reality allows you to immerse yourself in the atmosphere of historical events and visualize abstract historical objects. When developing the augmented reality applications, it is important to take into account design and functionality features depending on the target audience and purpose. The augmented reality technology, together with gesture recognition, can open up new ways of human-computer interaction, for example, the restore an amphora from shards or reconstruct an ancient column based on the fragments, controlling parts of an artifact using gestures (Saggio & Bora, 2011).

The Usage of the AR/VR/MR Technologies in the Historical Education

Garcia described the HARA augmented reality mobile application for studying the historical period associated with the American colonization in the Philippines based on flashcards with historical events (Garcia, 2020). Another example of the flashcards usage in the study of the history of chemistry based on the combination of game-based learning with augmented reality technology is considered in (Wang et al., 2017). Gherardini et al. (2018) considered the implementation of the reconstruction of sculptures based on a combination of 3D modelling and photogrammetic techniques, as well as combining with a video stream of a real scene (Gherardini et al., 2018). Baharuddin et al. (2020) explored the possibilities of using augmented reality to visualize content in animation history and art history classes, and noted an increase in student engagement in the learning process and improved social collaboration skills (Baharuddin et al., 2020). The effectiveness of the augmented reality usage in the study of the ancient history and the cultural heritage of Indonesian through the perception of the visual images is confirmed in the research (Utami & Lutfi, 2019).

The possibilities of the augmented reality usage as navigation tool for walking tours and as an educational tool for studying the cultural heritage of the city of Santiago de Chile are considered in the paper (Joo-Nagataa, 2017). Mokhsin et al. (2019) described the development of the ARMyPat augmented reality application to get acquainted with the historical figures of Malay and their exploits through the participation in the fighting game built into the application and noted the importance of such an application not only for the interactive study of history, but also for the development of the spirit of patriotism among young people (Mokshin et al., 2019). Azhar et al. (2019) developed an augmented reality app to explore the story of the fall of the Melaka Empire. They designed their app in such a way that users can learn history through an AR book and test their knowledge by taking a quiz (Azhar et al., 2019). The acquaintance with the life story of the ancient Roman poet Ovid and the cultural heritage of Ancient Rome is implemented in the augmented reality application OvidAR. The users of the application can immerse themselves in the life of Ancient Rome, see what the buildings of that time looked like (Boboc et al., 2019).

Let's consider some iOS-applications for the history learning with the help of the augmented reality. The WDR AR 1933-1945 application immerses schoolchildren in the terrible atmosphere of World War II from the hell of concentration camps to the bombing of civilians. In the center of the classroom in augmented reality, students become involuntary participants in the events of those sad years, they see and hear the memories of war children from besieged Leningrad, Cologne and London, who were subjected to air attacks. The Pal-

aeoGo app is designed to immerse you in the era of dinosaurs. 3D-models of tyrannosaurs, dilophosaurus, pteradactyls and mammoths allow not only to view dinosaurs and mammoths from different angles, but also to get acquainted with the description. The AR History - 3D Monuments app allows you to walk through the ruins of the ancient Colosseum, touch the secrets of Stonehenge and El Castillo pyramid in Chichen Itza.

The usage of the above applications with augmented reality as educational tools were presented in the Figure 1.

Fig. 1. The examples of the learning history with the help of mobile iOS applications: WDR AR 1933-1945 (A), PalaeoGo (B), AR History - 3D Monuments (C)

Learning History Through the AR/VR/MR Tourists' Tours and Museum Visiting

In recent years, there has been a stage of intellectualization of museums through the introduction of advanced innovative technologies. A striking example is the implementation of a project based on artificial intelligence technology, which made it possible not only to see the live" Salvador Dali, to hear his voice, but also to take pictures with him in the Dali Museum in Florida. The introduction of such projects contributes to better memorization of information, immersion in the world of art and history through direct participation in events, developing new ways of gaining knowledge (Billock, 2019).

Marti´-Testo´n et al. (2021) described the development of a mixed reality application for an archaeological museum that allows visitors to experience new information about the history of antiquity in an interactive and entertaining way (Marti´-Testo´n et al., 2021). Seo et al. (2010) discuss the prospects for the development of personalized guides with animated virtual assistants based on the recognition of the current location of the tourist and graphic primitives on cultural heritage monuments for overlaying 3D-objects. Features of the guide implementation included highlighting key points using the SIFT descriptor and matching descriptors to determine the desired image based on the nearest neighbour algorithm, as well as highlighting rectangles based on contours and tracking camera position to correctly display content in augmented reality (Seo et al., 2010).

The approaches to the reconstruction of historical artefacts can improve the perception of historical and cultural values and contribute to the improvement of personal knowledge. The visitors to the museum experience difficulties in perceiving the destroyed monuments, mosaics or rock inscriptions. Their perception and imagination is limited due to lack of knowledge in this area. AR/VR/MR are able to overcome this limitation and reproduce the original look of a historical artefact. Gherardini et al. described the development of an application for the reconstruction of museum exhibits such as ancient mosaics and lion sculpture, and demonstrated the effectiveness of the application for the perception of the original appearance of historical exhibits (Gherardini et al., 2019).

The aims of the paper are 1) the investigation of the modern approaches for the implementation of the augmented and virtual reality to improve the quality of teaching history and the fascination of excursions; 2) the development of a 3D-model of a disappearing monument of cultural heritage on the example of the Monzhene house (Kessler's castle); 3) the development of an augmented reality application for immersion in the history of the native land and acquaintance with rare monuments of the cultural heritage; 4) the investigation of the effectiveness of the augmented reality application in the history learning of the native land and the role of the augmented reality technology for the formation of an archive of digital virtual twins of disappearing cultural heritage monuments.

Methodology and Research

A feature of the development of an augmented reality application is its focus on the reconstruction of rare, almost disappearing objects of cultural and historical heritage that are not included in the list of attractions of popular tourist tours. Kessler's estate, also known as the castle (house) of Montzhene, is a medieval castle in the neo-Gothic style and belongs to the category of disappearing architectural and historical sights of Crimea that have lost their original appearance. The reconstruction of such rare objects of cultural heritage is of great importance for the preservation of the culture and history of various peoples living in the territory of Crimea. Augmented and virtual reality technologies can contribute to the creation of an archive of digital virtual twins aimed at restoring architectural monuments. Such reconstruction in augmented reality is much cheaper than the real reconstruction of buildings. It should also be noted that some cultural heritage sites are so destroyed that they require restoration from scratch. The reconstruction of such disappearing cultural heritage objects begins with a detailed study of archival photographs. In the case of the Kessler's manor, we were able to study photographs of the facade, including drone shots to understand the proportions and structure of the building, but were unable to find archival photographs of the rooms to enable a full immersive tour of the castle.

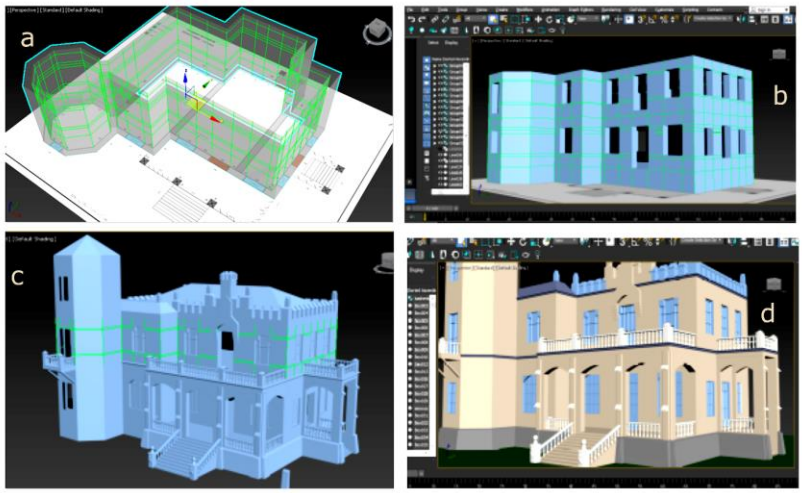

Fig. 2. The stages of the 3D-model of Monzhene's estate creation that were developed by authors

The research methodology consists of the following main stages: studying archival photos, creating a plan-drawing of the estate frame in Paint, loading drawings into 3Ds Max as splines, building up the walls of the model frame and decorative elements, creating the final 3D model of the estate, designing a mobile application, the use of marker technology and computer vision algorithms to "bind" the model to the marker image and analyze the streaming data from the device's camera to reproduce the 3D model on the ground, test the model in the classroom in the lesson on the study of the history of the native land, conduct and analyze the results of the questionnaire. Figure 2 shows the stage of building the walls of the 1st floor of the Monzhene's estate based on the created drawing (2a), building the frame (2b), editing the polygons of the second floor of the Monzhene's estate (2c) and painting the model (2d).

The process of building up the walls took place in this way: first, according to the drawings, lines were drawn, which, closing at one point, formed splines. Further, the splines were assigned the editable poly property, which allows you to work with polygons, vertices and edges of the element. A specific polygon (polygons) was selected, which needed to be increased, and the extrude method was applied to it, which is used to extrude polygons in one plane. After building up the main walls, window and door openings were cut out in them, according to the drawings. The battlements of the walls were developed as complex figures, from various simple parts and figures, in some places the bevel tool was used. After the 3D model was built, it was necessary to give it colours and textures to the polygons, for subsequent visualization in the application. Despite the fact that 3Ds Max has its own built-in material library, the Corona Renderer package was chosen for texturing as an addition to 3Ds Max, since this package provides more convenient material map functionality and a large number of material templates for subsequent rendering of pseudo-historical images of our application.

The initial state of the Monzhene's estate and its reconstruction based on 3D modelling are shown in Figure 3.

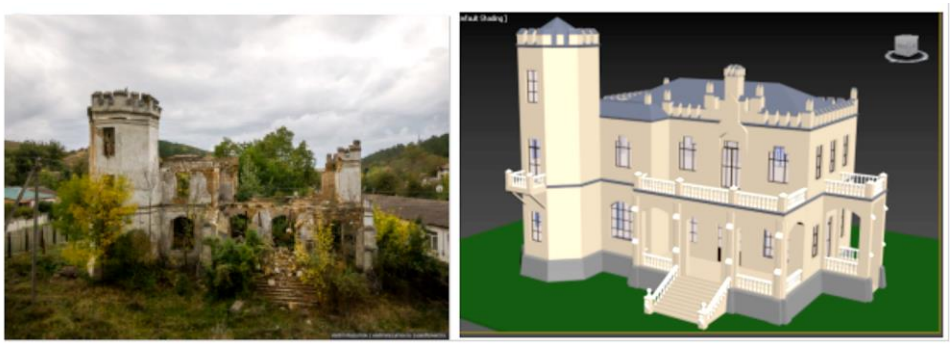

Fig. 3. The real state of Monzhene's estate (author is Vadim Razumov[2]) on the left, the 3D-model of Monzhene's estate is made by authors on the right

Fig. 4. The results of the mobile application with 3D-models of Monzhene's estate (on the left) and the fountain in front of the castle in the augmented reality (on the right)

New technologies make it possible to analyze the user's environment based on the analysis of data coming from motion sensors and geolocation coordinates, as well as a result of video stream image recognition, which contributes to the development of teaching methods based on the personalization of educational content that augments reality (Kysela & Sˇtorkova´, 2015).

Results

For augmented reality application development we used a 2D image tracking technology with 3D model of Monzhene's castle overlay with the help of the augmented reality software development platform Vuforia and cross-platform engine Unity3D. The results of the augmented reality application are presented in Figure 4.

The developed application was used in a lesson on the study of the history of the native land. 17 pupils in age from 13 to 15 years old took part in the survey. We asked the following questions.

[2] vadimrazumov.ru/694201.html

1. Was the augmented reality app useful in the lesson? (12 pupils (70.59%) answered "yes", 3 pupils (17.65%) found it difficult to answer, 2 pupils (11.76%) answered "no")
2. What did you like the most when using the application with augmented reality (animation when the castle was appeared, the 3D model of the castle itself, battlements, balconies, etc. (building details), fountain and castle surroundings)? (7 pupils (41.18%) liked the 3D model, 5 pupils (29.41%) paid attention to small details of the castle, 4 pupils (23.53%) noted the elaborateness of the castle's environment, one pupil (5.88%) found it difficult to answer).
3. What architectural style does Monzhene's castle belong to? (11 pupils (64.71%) remembered that the castle belongs to the Neo-Gothic, 6 pupils (35.29%) did not remember the style or gave the wrong answer)
4. Remember at least one fact from the history of the castle of Monzhene? (13 pupils (76.47%) remembered at least one historical fact about the castle, 4 pupils (23.53%) could not answer).
5. Did you know before this lesson about the existence of the Monzhene's castle? (15 pupils (88.24%) had never heard of the Monzhene's castle before this lesson, 2 pupils (11.76%) had heard of the castle from their parents).
6. Has augmented reality helped us understand what the castle looked like in the past? (15 pupils (88.24%) answered "yes", 1 pupil (5.88%) found it difficult to answer, 1 pupil (5.88%) answered "no").
7. What did not like when using the augmented reality application in the classroom? (5 pupils (29.41%) noted that there were difficulties with application installation (operating system version incompatibility, low Internet speed when downloading the application), 2 pupils (11.76%) noted the lack of realism, the remaining 10 pupils (58.83%) did not highlight any shortcomings).

Thus, among the advantages, schoolchildren noted the opportunity to view the castle from all sides and study its surroundings, the opportunity to explore small details when getting acquainted with the architectural style (neo-gothic). In general, the students were animated and engaged in working with the application and exploring the castle in augmented reality.

Conclusion

It should be noted the importance of developing applications with augmented reality for creating 3D models based on rare archival photos, since the use of the augmented and virtual reality technologies can leave the digital twins of the most important monuments of the historical and cultural heritage in the memory of the future generation, if it is impossible, for one or another reason, to preserve and reconstruct the real historical objects. In the future, it is planned to reconstruct in augmented reality a detailed landscape of the adjacent territory of the Monzhene castle of that time to increase the realism of perception and reconstruction in augmented reality of other disappearing monuments. The use of the developed application with augmented reality in the lesson on the study of the native land history demonstrated greater involvement and activity of students.

Conflicts of Interest: The authors declare no conflict of interest.

Publisher's Note: Serbian Geographical Society stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

Azhar, N. H. M., Diah, N. M., Ahmad, S. & Ismail, M. (2019). Development of augmented reality to learn history. *Bulletin of Electrical Engineering and Informatics*, *8*(4), 1425-1432.

Baharuddin, N. B., Rosli, H. & Juhan, M. S. (2020). Constructivism Learning Environment by Using Augmented Reality in Art History Cou*rse*. *International Journal of Academic Research in Business and Social Sciences*, *10*(8), 13-25.

Billock, J. (2019). Smithsonian Magazine. With a Little Help From A.I., the Dali Museum Brings the Famed Surrealist to Life. Available at: https://www.smithsonianmag.com/travel/with-little-help-from-ai-dali-museum-brings-famed-surrealist-to-life-180972127/, accessed: 01.02.2022.

Boboc, R.G., Chiriac, R. & Antonya, C. (2021). How Augmented Reality Could Improve the Student's Attraction to Learn Mechanisms. *Electronics*, *10*, 175.

Boboc, R.G., Duguleanaˇ, M., Voinea, G., Postelnicu, C., Popovici, D. & Carrozzino, M. (2019). Mobile Augmented Reality for Cultural Heritage: Following the Footsteps of Ovid among Different Locations in Europe. *Sustainability*, *11*, 1167.

Cai, S., Liu, E., Shena, Y., Liu, C., Li, S. & Shen, Y. (2020). Probability Learning in Mathematics using Augmented Reality: impact on Student's Learning Gains and Attitudes. *Interactive Learning Environments*. *28*(5), 560-573.

Cai, S., Wang, X., & Chiang, F. (2014). A Case Study of Augmented Reality Simulation System Application in a Chemistry Course. *Computers in Human Behaviour*, *37*, 31-40.

Challenor, J. & Ma, M. (2019). A Review of Augmented Reality Applications for History Education and Heritage Visualisation. *Multimodal Technologies and Interaction*. *3*(2), 39.

Chong, H & Yeo, K. (2016). Why Students Fail in History: A Minor Case Study in Malaysia and Solutions from Cognitive Psychology Perspective. Mediterranean Journal of Social Sciences, 7(1), 517-526.

Dirgantoro, B. P. (2021). Learning History Through Augmented Reality. Journal of Game, Game Art and Gamification, 6(1), 14-20.

Dyulicheva Y. (2020). The Use of Augmented Reality Technology to Improve the Efficiency of Teaching. *Informatics in School*, *156*(3), 37-46. [Дюличева, Ю. Ю. (2020). Применение технологии дополненной реальности для повышения эффективности преподавания. Информатика в школе, 156(3), 37-46.]

Dyulicheva, Y., Gaponov, D., Mladenović, R., & Kosova, Y. (2021). The virtual reality simulator development for dental students training: a pilot study. Proceedings of the 4th International Workshop on Augmented Reality in Education (AREdu 2021). *CEUR Workshop Proceedings*, *2898*, 56–67.

Garcia, M. B. (2020). Augmented reality in history education: an immersive storytelling of American colonisation period in the Philippines. *International Journal of Learning Technology*, *15*(3), 234-254.

Gherardini, F., Mattia, S. & Francesco, L. (2018). 3D Virtual Reconstruction and Augmented Reality Visualization of Damaged Stone Sculptures. *IOP Conference Series: Materials Science and Engineering*, *364*, 012018.

Gherardini, F., Mattia, S. & Francesco, L. (2019). Enhancing Heritage Fruition Through 3D Virtual Models and Augmented Reality: an Application to Roman Artefacts. *Virtual Archaeology Review*, *10*(21), 67-79.

Joo-Nagataa, J., Martinez Abadb,F., Garci´a-Bermejo Ginerc, J. & Garci´a-Pen□alvoc, F. (2017). Augmented Reality and Pedestrian Navigation through its implementation in m-learning and e-learning: Evaluation of an Educational Program in Chile. *Computers & Education*, *111*, 1-17.

Kysela, J. & S˘torkova´, P. (2015). Using augmented reality as a medium for teaching history and tourism. *Procedia - Social and Behavioral Sciences*, *174*, 926 – 931.

Liu, X., Liu, Y. & Wang, Y. (2019). Real Time 3D Magnetic Field Visualization Based on Augmented Reality. 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR). Osaka, Japan.

Marti´-Testo´n, A., Mun□oz, A., Solanes, J. E., Gracia, L. & Tornero, J. (2021). A Methodology to Produce Augmented-Reality Guided Tours in Museums for Mixed-Reality Headsets. *Electronics*, *10*, 2956.

Marti´n, A. C., Alario-Hoyos, C., & Delgado Kloos, C. (2019). Smart Education: A Review and Future Research Directions. *Proceedings*, *31*(1), 57.

Mokhsin, M., Zainol, A. S., Ibrahim, E., Mohd Som, M. H., Basit, K., & Azman, A. (2019). ARMyPat: Mobile Application in Learning Malay Historical Patriots Using Augmented Reality. In: Kacprzyk, J. (ed.), *Intelligent and Interactive Computing. Lecture Notes in Networks and Systems*, *vol. 67*, 425-445. Singapore: Springer.

Rahmawati, N. D., Buchori, A., & Wibisono, A. (2022). Effectiveness of VAR (Virtual Augmented Reality)-Based Educational Games in Trigonometry Learning in University. *Proceedings of the 2nd International Conference on Education and Technology (ICETECH 2021)*. 266-269.

Saggio, G. & Borra, D. (2011). Augmented Reality for Restoration/Reconstruction of Artefacts with Artistic or Historical Value. In: A. Y. Ching Nee (ed.), *Augmented Reality - Some Emerging Application Areas*, 59-86. Rijeka, Croatia: In Tech.

Seo, B., Kim, K. & Park, J. (2010). Augmented Reality-Based On-Site Tour Guide: A Study in Gyeongbokgung. In: Koch, R., Huang, F. (eds.), *Computer Vision – ACCV 2010 Workshops. ACCV 2010. Lecture Notes in Computer Science, vol. 6469*, 276-285. Berlin, Heidelberg: Springer.

Sung, N., Ma, J, Choi, Y. & Hong, M. (2019). Real-Time Augmented Reality Physics Simulator for Education. *Applied Sciences*, *9*(19), 4019.

Utami, I. & Lutfi, I. (2019). Effectivity of Augmented Reality as Media for History Learning. *International Journal of Emerging Technologies in Learning (iJET)*, *14*(16), 83-96.

Vairinhos, M., Raposo, R. & Pereira, E. (2021). Augmented Reality Fire Simulation in Classroom and Office Environment. 15Th International Technology, Education and Development Conference. *INTED2021 Proceedings*, 7443-7451.

Wang, S., Chen, K., Hou, H. & Li, C. (2017). A science history educational board game with augmented reality integrating collaborative problem solving and scaffolding strategies. *Workshop Proceedings of the 25th International Conference on Computers in Education*, 40-47. New Zealand: Asia-Pacific Society for Computers in Education.