Ogata, H. et al. (Eds.) (2015). Proceedings of the 23rd International Conference on Computers in Education. China: Asia-Pacific Society for Computers in Education

A Preliminary Creative Process Exploration of Learners' Behavioral Patterns in a Collaborative Green Building Design Learning Activity Using Minecraft

Shu-Ming WANG[a], Huei-Tse HOU[b*] & Shu-Ping CHANG[c]
[a]*Department of Information Management, Chinese Culture University, Taiwan*
[b]*Graduate Institute of Applied Science and Technology, National Taiwan University of Science and Technology, Taiwan*
[c]*Department of Multimedia Design, Chihlee Institute of Technology, Taiwan*
*hthou@mail.ntust.edu.tw

Abstract:
In the era of knowledge economy, creativity can be a critical skill to advance the science and technology development. Thus, in science education, researchers emphasize the importance of creativity and have been advocating the importance of teaching creative thinking skills. While previous studies regarded creativity as an internal process or personality attributes; nonetheless, creativity also can be a collaborative product of social and cognitive interaction among knowledgeable individuals. To understand how creativity can be collaboratively produced and thus could provide adequate guidance for creative collaboration, it is important to depict the patterns of interaction during creative process. However, to the authors' best knowledge, relative little attention has been devoted to the process of collaborative creativity. In order to address this literature gap, this preliminary study employed a project-based creativity learning activity, which required students to collaboratively design a green building. To design a green building, students have to comprehend and negotiate on the advantages and disadvantages of various energy sources and come up with creative ideas to efficiently reduce energy consumption of the building. This learning activity was expected to improve students' understanding of the mechanism and cost of various kinds of energy generation by asking students to negotiate on the advantages and disadvantages of varied energy sources when designing the green building. In order to depict the creative process, this study employed a novel approach, which combined quantitative content analysis (QCA) and lag sequential analysis (LSA) to illustrate learners' behavioral patterns exhibited in the creative process. By improving our understanding of the process of collaborative creativity, we could thus provide adequate guidance for students to go through the creative process. Students might not be born with creativity or know how to think creatively, but the instructor can guide them going through creative process and collaboratively work with each other to produce creative ideas of science and technology development. The novel approach to depict the creative process can be employed to subsequent collaborative creativity research for improving our understanding of the creative process.
Keywords: Creativity, green technology, collaborative learning, behavioral analysis.

1. Introduction

Creativity was regarded as a higher order cognitive skill as it can be complex and abstract (DeHaan, 2011). Creativity do not only manifest in fine arts and design, but as well in many practical disciplines. When it comes to science and technology development, there would be multiple solutions. Scientists have to think of the problem in unconventional ways and explore unusual alternatives before new discoveries and innovations could happen. In this manner, creative thinking could be the root of innovation and is considered as a critical ability to advance the science and technology development. To promote creative thinking in science and technology development, researchers have been advocating the importance of teaching

creative thinking skills in science education (DeHaan, 2011; Kind & Kind, 2007). Creativity is regarded as the ability to produce novel ideas or apply innovative strategy to solve problem. In addition, the proposed ideas need to be original, useful and feasible for being considered as creative (Amabile, 1983; Sternberg, 2006). Previous creativity research mostly regarded creativity as an internal process or personality attribute of an individual. Besides the internal process, researchers have proposed the idea of collaborative creativity arguing that creativity is the product of cognitive and social interaction among individuals of diverse background and experience (Mamykina, Candy, & Edmonds, 2002). As to collaborative creativity, the development of creative outcomes becomes the result of a creative process among group members that involves varied phases of cognitive and social interaction, such as idea generation, idea selection, and idea validation. In different phases of the creative process, group member have to employ different strategy in order to produce better creative outcomes (Runco & Chand, 1995; Treffinger, 1995). For example, in the phase of idea generation, group members have to propose as many ideas as possible without any judgment or boundary. Associative thinking could be an important cognitive skill to be employed in this phase. However, in the phase of idea evaluation or validation, they need to employ critical thinking to apply criteria and rules to evaluate the ideas for it can be more feasible.

Previous creativity assessments generally assess the individual's personality attribute or evaluate one's idea generating ability from multiple dimensions, such as fluency, cognitive flexibility, and originality (Kirton, 1976; Torrance, 1995). However, these tests could not depict the cognitive and social interactions in the creative process. By observing the patterns of cognitive and social interaction among group members in the creative process and comparing their creative outcomes could help us better understand how the collaborative creativity is formed. In addition, with this knowledge, the instructor would be able to provide adequate guidance to learners in the creative process.

Nonetheless, to the authors' best knowledge, there is quite limited research that explored the patterns shown in the creative process in the context of collaborative creativity. To address this literature gap, this preliminary work designed a project-based creativity learning activity, which required students to work as a team and used asynchronous online discussion board to support their collaboration. The subject of the project-based creativity learning activity is to design a green building for a family with children of around 5 year-old. To design a green building, students have to come up with creative ideas of how to efficiently utilize the natural resources for reducing energy consumption. Also, they have to evaluate the alternatives of the different materials and design they would like to apply in the green building design project. It is an important learning goal for students to comprehend the advantages and disadvantages of various energy sources in green technology. Therefore, in the creativity learning activity, we expected students could collaborate on proposing creative ideas of how to design a building that could efficiently utilizing energies and create a comfortable space for living. The details of the creativity learning activity are delineated in section 2.2. This study then employed a novel analysis approach that integrates the quantitative content analysis (QCA) and lag sequential analysis (LSA) to explore the learners' content structure of and behavioral patterns exhibited in the creativity learning activity, which students used Minecraft to design a green building. The procedure of QCA and LSA will be delineated in section 2.3. Combining the results of QCA and LSA, the purpose of this preliminary work is to propose a novel approach to look into the formation of the collaborative creativity from a process perspective. The initial findings of this preliminary study could improve our understanding of how learners collaborate during the creative process. In addition, suggestions for guiding students' interaction would be proposed based upon the findings.

2. Research method

2.1 Participants

Participants of this study were 57 students from an institute of technology in northern Taiwan. These Students were of department of Multimedia design and were enrolled in a course – The

principles and practices of e-learning. This course was to introduce the current status and novel applications of the e-learning. Also, software and skills for developing digital content were also introduced to improve students' ability to produce e-learning content. In the course, students were asked to collaboratively work on the assignments using asynchronous online discussion board for they can experience learning with the support of information technology. The discussion board was also used for students to work on the creative project in this study.

2.2 The project-based creativity learning activity

A project-based creativity learning activity was employed in the course. Students were grouped into 10 groups, each with 5 to 6 students. Each group was asked to design a green building for a family with children of around five years old. With this goal, each group have to take into account of how to efficiently utilize the natural energy resources, such as solar, water or wind, when designing the building. Meanwhile, when they design the interior of the building, they also have to consider the safety issue of the space for children. Students were encouraged to express their creativity when designing the green building. This learning activity was expected to improve students' understanding of the mechanism and cost of energy generation of different kinds by asking them to negotiate on the advantages and disadvantages of varied energy sources. In the end of the creative project, students had to prepare a document explaining their design concept and features of their work.

The tool that students used to design the green building is Minecraft, which is a game that allows players to build structure using blocks. Figure 1 shows a sample screenshot of Minecraft. Unlike conventional video games, Minecraft is more like a sandbox, or an open world. There are no clear objectives, challenges or levels for the gamers to complete (Short, 2012). With the freedom to play, Minecraft has been regarded as a creative tool for building structures (Schifter & Cipollone, 2013). Searching YouTube using keyword – "Minecraft" would return a long list of videos showing the creative structures built using Minecraft. These videos mostly demonstrate a walkthrough of the structures with no particular stories or game plots. In Minecraft, players can build anything they can imagine of in a virtual 3D world. With its freedom of play and ease of use, Minecraft has been used as a teaching tool in various subjects (Al-Washmi et al., 2014; Schifter & Cipollone, 2013; Wendel et al., 2013). While computer-aided design (CAD) tools, such as Sketch or AutoCAD, requires a considerable amount of training before students can use the functions to design structures, Minecraft is relatively simple to use. Moreover, the game-like environment of Minecraft would also promote students' engagement in the creative project of this study. In this manner, students would be able to focus on designing the green building rather than trapped by the complicated functions of CAD software.

Before the start of the creative project, the instructor introduced the green building to give students the basic ideas for they can apply to the project and further collect more information when designing the green building. Students had three weeks to work on the creative project. To document students' interaction, an asynchronous discussion board were setup for each group. Each group had a dedicated discussion board and was asked to discuss the creative project on the discussion board. After three weeks, all the messages on the discussion board were retrieved for further analysis. There were 1109 messages in students' three weeks discussion.

2.2 The assessment of the creative performance

Previous creativity studies usually assess the creativity performance of individuals by asking them to come up with ideas of how one can use rubber bands or bricks. Then, the creative performance would be assessed by several indicators, such as the creative fluency (the number of ideas generated), cognitive flexibility (the extent of the diversity of ideas generated), and the originality (Torrance, 1965). Nonetheless, this approach might not be adequately translated to their creative performance on particular creative tasks. Another approach is to assess the creative performance by evaluating the creative outcome (Amabile, 1983). Echoing this notion, Besemer (1998) proposed Creative product analysis matrix (CPAM) to assess the creative performance of creative products, There are three components

of CPAM, namely the *novelty*, which reflects the newness aspects in a product, the *resolution*, which denotes how well the product does what it is supposed to do and the *elaboration and synthesis*, which represents the aesthetic and level of details of a product. This study adapted CPAM as the framework to assess each group's project outcome using conclusive measures for each measure. In the preliminary stage of this study, each group's creative project performance was evaluated by one expert who is knowledgeable of the green building and familiar with Minecraft.

2.3 The procedure of QCA and LSA

This study employed a novel approach to depict the creative process in the learning activity. In specific, this study was to explore the content structure and behavioral patterns of students' interaction on the green building design project. Therefore, quantitative content analysis (QCA) and Lag sequential analysis (LSA) were employed to analyze the retrieved message (Bakeman & Gottman, 1997; Gunawardena, Lowe, & Anderson, 1997). QCA begins with a pre-defined coding scheme. Previous studies have proposed coding schemes, such as Interaction analysis model (IAM), Revised Bloom's Taxonomy (RBT), to analyze learners' online discussion; nonetheless, to the authors' best knowledge, there is no specific coding scheme to depict the creative process. Therefore, we developed a coding scheme to delineate the creative process by reviewing previous creativity literature (Botella et al., 2013; Feldhusen & Ban Eng, 1995; Nemiro, 2002; Treffinger, 1995). In this study, we decomposed the creative process into five phases and assigned a code to each phase. The five phases are (1) Understanding the problem (Cre1); (2). Divergent exploration (Cre2); (3) Idea generation (Cre3); (4) Selective focusing (Cre4); (5) Idea development and evaluation (Cre5), respectively. In addition, we assigned two codes to represent the off-topic discussions. Cre61 denotes off-topic discussion that involves casual social interaction, such as greeting. Cre62 refers to off-topic discussion that involves encouragement, promoting team morale, which is considered a factor that could promote positive teamwork climate (Abedin, Daneshgar, & D'Ambra, 2011). To conduct QCA, we invited two experienced coders jointly coded the retrieved messages using the coding scheme to ensure the reliability of the coding results. Kappa coefficient was calculated to assess the inter-rater reliability. The Kappa coefficient of the coding results is 0.72, suggesting high inter-rater reliability (Rourke & Anderson, 2004). The coding results of each group were arranged to represent the distribution of their discussion on each phase of creative process. With the QCA results, this study further conducted LSA to analyze the behavioral patterns of learners' interaction. LSA can be used to determine the statistical significance of a behavioral sequences, or the sequential order of the appearance of behaviors. In other word, LSA is used to determine an observed sequence, i.e. the appearance of one specific behavior followed by another specific behavior, is not a outcome of random chance. LSA begins with a series of matrix calculations (Bakeman & Gottman, 1997), which are the calculation of (1). sequential frequency transfer matrix; (2). condition probability matrix; (3). expected-value matrix. Next, the significance level of each behavioral sequence would be determined by calculating Z-score using previous matrices. Based on the Z-score table, the last step is to draw a sequential transfer diagram for depicting the significant sequences using the data in the z-score table. Only those behavioral sequences with z-score higher than 1.96 was considered as significant ($p < 0.05$) and depicted in the sequential transfer diagram.

3. Data Analysis and Results

3.1 Results of QCA

The distribution of QCA results of each group is as shown in Table 1. Regarding the level of engagement in the learning creativity, group 4, 6, 8 participated the online discussion more frequent than other groups in terms of the number of message posted. Nonetheless, group 10 is of the lowest level of participation among all groups. In fact, this group didn't work on developing ideas in the discussion board. This study thus excluded group 10 for subsequent

analysis. Overall, students' discussions were mostly on 'idea development and evaluation (Cre5)' and 'Off-topic casual social interaction (Cre61)'. In the learning activity of this study, the instructor gave students clear goal, which was to design a green building for a family with children. As the results of QCA showed, these students generally jumped to the idea development phase without seeking references or explore other possibilities. This could limit their creative performance. On the other hand, the large number of casual social interaction is a common phenomenon in asynchronous online discussion (Lin, Hou, Wang, & Chang, 2013). Nonetheless, by giving students clear discussion topic and rubric for grading their performance, student could more focus on meeting the goals of each phase.

Figure 1: The project outcome of the group 1

Figure 2: The project outcome of the group 6

As to the diversity of the distribution of QCA, Group 1 and 3 showed more diversity than other groups. Group 5 to 9 showed quite similar patterns as their discussions were mostly on developing the ideas and off-topic social interaction. In the creative performance assessment, group 1 showed more distinct elements in their project outcome, such as a garden and waterfalls on the roof to reduce the heat from sunlight that would raise the room temperature. Group 1 received high score on the *resolution* dimension. Nonetheless, group 1 didn't get high score on *elaboration and synthesis* dimension. This finding might attribute to their lower amount of discussion in comparison with other groups. Figure 1 showed a screenshot of the project outcome of group 1.

On the other hand, the project outcome of group 6, which has the highest number of 'idea development and evaluation', received the highest score on the elaboration and synthesis dimension as the green building they designed was relatively larger than other groups. And the decoration of the building is more detailed in comparison with the project outcomes of other groups. Figure 2 showed the screenshot of the project outcome of group 6.

Table 1: The results of QCA

	Cre1	Cre2	Cre3	Cre4	Cre5	Cre61	Cre62	Total
G1	1	7	9	1	29	49	2	98
G2	0	0	0	2	60	68	10	140
G3	0	5	4	0	31	31	4	75
G4	0	0	3	1	32	118	3	157
G5	0	0	2	0	38	28	4	72
G6	0	0	0	1	98	73	9	181
G7	0	0	0	0	58	56	2	116
G8	0	0	0	0	85	71	3	159
G9	0	0	0	0	39	58	0	97
G10*	0	6	0	0	0	8	0	14

*: Group 10 was excluded from the further analysis due to low level of participation.

3.2 Results of LSA

In general, all groups showed behavioral continuity patterns of 'idea development and evalution (Cre5)' and 'off-topic discussion (Cre61, Cre62)'. This finding suggested students could focus on developing the idea. Nonetheless, students' discussion could easily go to off-topic. This finding is similar to previous studies, which used online discussion as tool to support students' interaction (Lin et al., 2013).

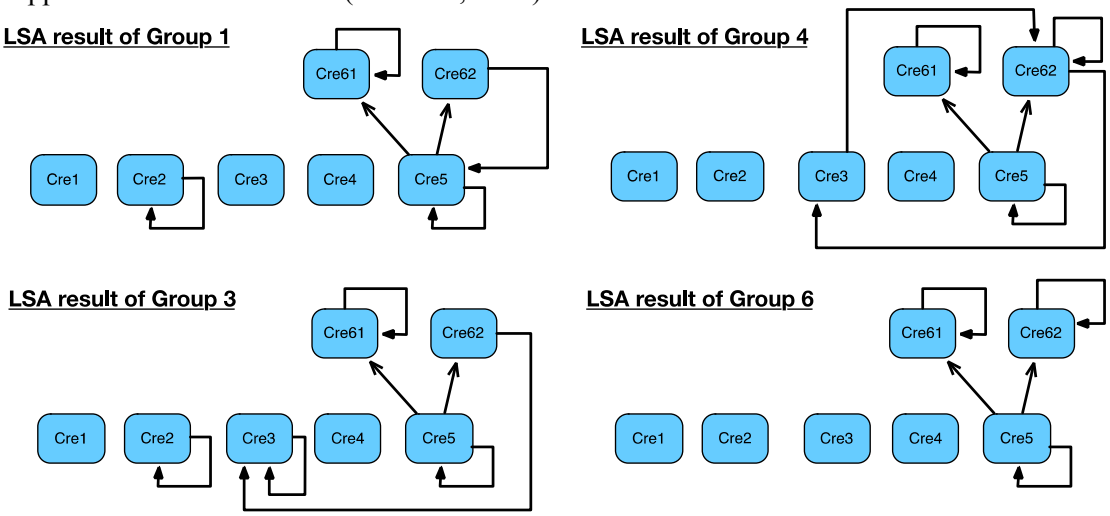

Figure 3: LSA results of selected groups

As for the patterns of particular groups, group 1 showed the most diversified interaction patterns, which is as shown in top-left panel of figure 3. In specific, behavioral continuing patterns were observed in 'divergent exploration (Cre2)', 'idea generation (Cre3)', 'idea development and evolution (Cre5)' as well as 'off-topic discussion (Cre61, Cre62)'. We also observed a behavioral transition pattern from Cre5 to off-topic discussion (both Cre61 and Cre62). It is worth noting that group 1 showed a behavioral transition pattern from Cre62 to Cre5, suggesting when developing the ideas, the group members would give each other positive affirmation of the contributions to the project. Previous studies suggested that this kind of social interaction is helpful to promote the positive teamwork climate, which is considered beneficial to the team performance (Abedin et al., 2011). Similar patterns were also found in the results of LSA of group 3 and 4. As shown in figure 3, we observed a behavioral transition pattern from Cre62 to Cre3. Group 4 in particular, we found a loop from 'idea generation (Cre3)' between 'positive affirmation (Cre62)'.

Similar to the results of QCA, the results of LSA for Group 6 to 9 showed similar patterns. For an example of group 6, which is as shown in Figure 3, behavioral continuity

patterns of 'idea development and evaluation (cre5)' and 'off-topic discussion (cre61, cre62)' were observed. Meanwhile, behavioral transition patterns of 'idea development and evaluation (cre5)' to 'off-topic discussion (cre61, cre62)' were observed. These patterns were also found in group 7, 8, 9.

4. Conclusion and subsequent research

The primary purpose of this study was to propose a novel approach to delineate the creative process of a collaborative creativity learning activity. In this study, a learning activity of designing a green building was employed. Students were asked to discuss in the asynchronous discussion board. Afterward, all the messages were retrieved and analyzed using QCA and LSA from a process perspective. This study developed a coding scheme to depict the phases of a creative process as well as off-topic social interaction. Our major findings and its discussions are summarized as following.

First of all, in general, the QCA results of the current study lacked of diversity in terms of the creative phases. Most of the discussions were on 'idea development and evaluation (Cre5)' and 'off-topic discussion (Cre61 and Cre62)'. This finding could be attributed to that this study employed the learning activity in a natural setting without specific instructional strategy as guidance. In specific, the instructor only gave students the project goals and the context to design a green building for. Without adequate creative thinking skills at hand, students could jump to developing the green building immediately in order to achieve the project goal. Nonetheless, previous studies suggested that by giving students creative thinking techniques and adequate guidance to walk through the phases of creative process, students would be more able to produce better creative outcomes. The results of this preliminary work can be compared with those of future research that employs creative thinking instructional strategies, such as creative spiral (Resnick, 2007), or creative problem-solving (CPS) (Treffinger, 1995). In this vein, we would be able to delineate an effective creative collaboration process that thus can be used in science education or technology development. Therefore, students would be able to employ creative thinking to solve the ill-structured problems or technology development. Secondly, we observed a significant amount of off-topic social interaction in students' discussion. This phenomenon was frequently observed in online discussions (Lin et al., 2013). As casual social interaction requires less cognitive effort, student would easily turn to discuss things that are not related to the project. This situation could be alleviated by providing specific rubrics of the learning activity or collaboration script, which could be helpful to keep students on the track (Lin et al., 2013; Weinberger, Kollar, Dimitriadis, Mäkitalo-Siegl, & Fischer, 2009). Lastly, casual social interaction might not necessarily be detrimental to group members' collaboration on the project. On the contrary, casual social interaction could be a facilitator to form a positive knowledge sharing climate (Abedin et al., 2011) and was considered as a key to promote collaborative creativity (Sawyer, 2007). A free and relaxed environment that enables frequent casual social interaction could cultivate the creativity. Despite this preliminary study found a patterns from casual social interaction (Cre61) to idea generations and idea development (Cre5). Nonetheless, how casual social interaction could contribute to the collaborative creativity still requires further exploration. Future study could employ the process-oriented approach that this preliminary study introduced to analyze the relationship between the guided creative collaboration process and its creative outcomes to better understand the creative interaction patterns.

Acknowledgements

This research was supported by the projects from the National Science Council, Republic of China, under contract number MOST-04-2511-S-011-003-MY3, MOST-102-2511-S-011-001-MY3, MOST-100-2628-S-011-001-MY4, MOST-103-2511-S-034-001 and MOST-104-2511-S-034-002,

Ogata, H. et al. (Eds.) (2015). Proceedings of the 23rd International Conference on Computers in Education. China: Asia-Pacific Society for Computers in Education

References

Abedin, B., Daneshgar, F., & D'Ambra, J. (2011). Enhancing Non-Task Sociability of Asynchronous CSCL Environments. *Computers & Education, 57*(4), 2535-2547.

Al-Washmi, R., Bana, J., Knight, I., Benson, E., Afolabi, O., Kerr, A., . . . Hopkins, G. (2014). Design of a Math Learning Game Using a Minecraft Mod. *Proceedings of the 8th European Conference on Games Based Learning (Ecgbl 2014), Vols 1 and 2*, 10-17.

Amabile, T. (1983). The Social Psychology of Creativity: A Componential Conceptualization. *Journal of Personality & Social Psychology, 45*(2), 357-376.

Bakeman, R., & Gottman, J. M. (1997). *Observing Interaction : An Introduction to Sequential Analysis* (2nd ed.). New York: Cambridge University Press.

Besemer, S. P. (1998). Creative Product Analysis Matrix: Testing the Model Structure and a Comparison Among Products--Three Novel Chairs. *Creativity Research Journal, 11*(4), 333-346.

Botella, M., Glaveanu, V., Zenasni, F., Storme, M., Myszkowski, N., Wolff, M., & Lubart, T. (2013). How artists create: Creative process and multivariate factors. *Learning and Individual Differences, 26*(0), 161-170.

DeHaan, R. L. (2011). Teaching creative science thinking. *Science, 334*(6062), 1499-1500.

Feldhusen, J. F., & Ban Eng, G. (1995). Assessing and Accessing Creativity: An Integrative Review of Theory, Research, and Development. *Creativity Research Journal, 8*(3), 231-247.

Gunawardena, C. N., Lowe, C. A., & Anderson, T. (1997). Analysis of A Global Online Debate and The Development of An Interaction Analysis Model For Examining Social Construction of Knowledge in Computer Conferencing. *Journal of educational computing research, 17*(4), 397-431.

Kind, P. M., & Kind, V. (2007). Creativity in Science Education: Perspectives and Challenges for Developing School Science. *Studies in Science Education, 43*, 1-37.

Kirton, M. (1976). Adaptors and Innovators - Description and Measure. *Journal of Applied Psychology, 61*(5), 622-629.

Lin, P.-C., Hou, H.-T., Wang, S.-M., & Chang, K.-E. (2013). Analyzing Knowledge Dimensions and Cognitive Process of A Project-Based Online Discussion Instructional Activity Using Facebook in An Adult and Continuing Education Course. *Computers & Education, 60*(1), 110-121.

Mamykina, L., Candy, L., & Edmonds, E. (2002). Collaborative Creativity. *Communications of the ACM, 45*(10), 96-99.

Nemiro, J. E. (2002). The Creative Process in Virtual Teams. *Creativity Research Journal, 14*(1), 69-83.

Resnick, M. (2007). Sowing the Seeds for a More Creaitve Society. *Learning & Leading with Technology, 35*(4), 18-22.

Rourke, L., & Anderson, T. (2004). Validity in Quantitative Content Analysis. *Educational Technology Research & Development, 52*(1), 5-18.

Runco, M. A., & Chand, I. (1995). Cognition and Creativity. *Educational Psychology Review, 7*(3), 243-267.

Sawyer, K. (2007). *Group Genius : The Creative Power of Collaboration*. New York: Basic Books.

Schifter, C., & Cipollone, M. (2013). *Minecraft as a teaching tool: One case study*. Paper presented at the Society for Information Technology & Teacher Education International Conference 2013, New Orleans, Louisiana, United States.

Short, D. (2012). Teaching scientific concepts using a virtual world—Minecraft. *Teaching Science-the Journal of the Australian Science Teachers Association, 58*(3), 55-58.

Sternberg, R. J. (2006). The Nature of Creativity. *Creativity Research Journal, 18*(1), 87-98.

Torrance, E. P. (1965). *Rewarding creative behavior; experiments in classroom creativity*. Englewood Cliffs, N.J.,: Prentice-Hall.

Torrance, E. P. (1995). Insights about creativity: Questioned, rejected, ridiculed, ignored. *Educational Psychology Review, 7*(3), 313-322.

Treffinger, D. J. (1995). Creative Problem Solving: Overview and Educational Implications. *Educational Psychology Review, 7*(3), 301-312.

Weinberger, A., Kollar, I., Dimitriadis, Y., Mäkitalo-Siegl, K., & Fischer, F. (2009). Computer-Supported Collaboration Scripts. In N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, & S. Barnes (Eds.), *Technology-Enhanced Learning* (pp. 155-173): Springer Netherlands.

Wendel, V., Gutjahr, M., Battenberg, P., Ness, R., Fahnenschreiber, S., Gobel, S., & Steinmetz, R. (2013). Designing a Collaborative Serious Game for Team Building Using Minecraft. *Proceedings of the 7th European Conference on Games Based Learning, Vols 1 and 2*, 569-578.