Augmented Reality and Simulation in Promoting Creative Thinking Skills

Irish Mae T. Molina[1], Elisa N. Chua, PhD[2]

Department of Education, Division of Laguna, Philippines, Laguna State Polytechnic University, San Pablo Campus, Philippines
DOI: https://doi.org/10.55248/gengpi.5.0624.1584

ABSTRACT:

This study aimed to determine which among Augmented Reality Teaching Tool and Simulation Teaching Tool can promote Creative Thinking Skills. Moreover, this attempted to determine if there is a significant difference between the pre and post-test performance task score of the respondents when exposed to the different teaching tools. It also attempt to determine if there is a significant difference on the post – test task performance score on Creative thinking skills of grade 8 students in Science when exposed to the different teaching tool. The results indicated that the use of the Augmented Reality Teaching Tool led to an improvement in students' performance task scores related to their creative thinking skills, including creativeness, analytical thinking, and problem-solving. Similarly, the Simulation Teaching Tool also demonstrated a significant increase in students' task performance scores in these same areas. However, when comparing the effectiveness of the two teaching tools, the simulation showed a notably higher increase in post-test performance scores compared to augmented reality. This significant difference suggests that simulation as a teaching tool is particularly effective in enhancing students' creative thinking skills. Thus, the use of simulation in educational settings can substantially improve students' abilities in creativeness, analytical thinking, and problem-solving more effectively than augmented reality.

Keywords – Augmented Reality, Simulation, Creative Thinking Skills, Creativeness, Analytical Thinking and Problem Solving

Introduction:

Science is valuable because it is connected to technology and industry, which are crucial for national development. It provides systematic approaches for understanding the world, aiding students in honing their scientific inquiry skills, beliefs, and attitudes, such as objectivity, curiosity, honesty, and critical thinking. This contributes to the student's personal growth, future career, and overall life. These skills, values, attitudes, and traits also positively impact the student's community and the nation as a whole.

With the way assistive technology is developing, there are countless opportunities for students in special education. Technologies related to simulation and robotics offer a range of educational options that effectively address the unique learning requirements of every learner. The educational sector will continue to benefit from these revolutionary technologies as long as the technology industry keeps releasing new innovations.

In the Philippines and across the globe, there is ongoing discussion about a future grounded in science and technology and driven by a knowledge economy. Considering the skills and expectations necessary to thrive in this environment, along with the various challenges faced by science education in the country, it is essential to revaluate the vision for science education.

The Science Curriculum for Grades 1-10 in the Philippines is designed to develop individuals who are literate in science, technology, and ecology, and who are productive members of society. These individuals should possess the ability to communicate effectively, collaborate with others, maintain a lifelong learning mindset, and hold scientific beliefs and attitudes. These skills will be acquired via an inquiry-based curriculum that focuses information applicable to the actual world. These will be used in an educational setting that encourages the development of ideas and fosters respect for others.

Some scientific experiments can be dangerous or expensive in a traditional lab setting. New technologies allow students to experience these experiments safely and cost-effectively. Technology can allow provides specific learning experiences in which students can advance at their own speed while receiving timely feedback on their performance.

The primary outcome is a coherent, all-encompassing science curricular framework for elementary education that places a strong emphasis on the advancement of scientific inquiry. It focuses on basic scientific knowledge and abilities so that students can "learn how to learn."

In line with this, everyone who works with students wants them to do their best work, including parents, principals, and instructors. In order to do this, it's critical to look at new learning styles and determine whether there are more effective teaching methods. Teachers must teach their pupils to memorize facts in subjects like science, but they also need to help them comprehend the nature of science, apply ideas, and draw logical inferences.

Methodology:

This research used descriptive – experimental design using pre-test - post-test design. Descriptive experimental research design refers to a type of research methodology that combines elements of both descriptive and experimental research. In this approach, researchers aim to describe the characteristics of a population or phenomenon of interest while also using one or more variables to determine their effect on the result. A post-test is an evaluation administered to participants after they have undergone treatment as part of a research study. In this research, variables were analysed for possible significance of relationship among students in Grade 8 Science using innovative teaching tools such as Augmented Reality and Simulation. It provides an opportunity to predict scores and explain the significant relationship among variables.

The respondents of the study were the Grade 8 of Dayap National High School Main in the District of Calauan, Laguna which is consist of 545 students in their grade level whereas 100 of were selected as the respondents of the study during the Third Quarter of the school year 2023 – 2024.

The study made use of cluster sampling is a probability sampling technique where the population is divided into clusters for study. Researchers then randomly select clusters using either a simple random or systematic random sampling method to gather data and determine the unit of analysis. After that, they choose at random from these clusters to create a sample wherein all the respondents are from Grade 8.

Objective:

1. The research aimed to determine the use of Augmented Reality and Simulation in improving Creative Thinking Skills. To predict the condition of a specific weather event in the near future.

2. To promote a safe environment for the students when conducting their laboratory activities.

Results

Technology-enabled classes will result in more contemporary teaching and learning methods. This is because the usage of technology incorporates real-world difficulties, current informational resources, concept simulations, and connections with subject matter experts. Furthermore, learning through technology is seen to supplement traditional methods of teaching and learning.[7]

Utilizing AR approaches in teaching has a number of benefits. AR, for instance, helps reduce mistakes that result from students' incapacity to visualize ideas like chemical bonds since it enables object animation and thorough visualization. Another benefit of AR is that it makes things and ideas that are invisible to the human eye visible at either a large or micro scale. AR helps students comprehend the material better by displaying objects and concepts in a variety of ways and from a variety of viewing angles. [4]

Simulation can be used to boost students' creativity in natural science classes. The type of method employed in inquiry-based learning with simulation impacts students' problem-solving abilities. [2]

Simulation in teaching chemistry involves the use of computer-based models or virtual environments to replicate chemical phenomena, experiments, or processes. These simulations provide students with interactive, visualized experiences that develop their insight of complex chemical concepts. [8]

It support the notion that simulation can enhance creative thinking skills. They found that learners joined in simulation-based activities showed greater creativity in problem-solving tasks compared to those who did not engage in such activities. Simulation allows for the exploration of different settings and encourages learners to think outside the box, leading to improved creative thinking skills

Utilizing interactive simulations in the classroom can help science students develop various skills such as observation, measurement, prediction, variable control, hypothesis generation, and outcome analysis [5].

The following are the salient findings of the study

1. The result shows the students pre – test performance score in Augmented Reality that they are in "Imitative" level as to creativeness, "Marginal" level as to analytical thinking skills and "Needs Improvement" level as to problem solving while in the post – test performance score is on the "Ordinary" level as to creativeness, "Fair" level as to analytical thinking and "Good" level as to problem solving.

2. The result shows the students pre – test performance score in Simulation that they are in "Imitative" level as to creativeness, "Marginal" level as to analytical thinking skills and "Needs Improvement" level as to problem solving while in the post – test performance score is on the "Creative" level as to creativeness, "Excellent" level as to analytical thinking and "Excellent" level as to problem solving.

3. There is a significant difference between the pre-test and post –test task performance score of the respondents as to Augmented Reality and Simulation as teaching tools.

4. There is a significant difference on the post – test task performance score on Creative thinking skills of grade 8 students in Science when exposed to the teaching tool as to creativeness, analytical thinking and problem solving.

Table 1. Pre-test and Post-test Performance Score of the Student in Augmented Reality Group as to Creative Thinking Skills in terms of Creativeness

SCORE	Pre-Test		Post-Test		Interpretation
	F	%	F	%	
14-16	--	--	1	2	VC
12—13	--	--	9	18	C
8—11	1	2	35	70	O
4—7	46	92	5	10	I
0-3	3	6	--	--	P
Total	50	100	50	100	

Legend: 14-16 – Very Creative (VC), 12-13 – Creative (C), 8-11 – Ordinary (O), 4-7 – Imitative (I), 0-3 – Poor (P)

Table 1 shows the pre –test and post – test using Augmented Reality under Creativeness which shows development in the students' task performance. The result shows that the frequency of 46 or 92% with a verbal description of "Imitative" is the majority of the students score which means that the respondents in terms of their creativeness lacks in innovating it works they just copying the existing work rather than coming up with something new as what have been observe by the researcher the respondents answers was same on what have been information fed for them all throughout their answers was based on the information given while in their pre –test after using the Augmented Reality the frequency of their post-test are 35 or 70 % with a verbal interpretation of "Ordinary" which mean that from "Imitative" respondents tend to improve their ideas and concept to create valuable concept effectively and 9 or 18% with a verbal interpretation of "Creative" which means that the students can produce new and original concept of ideas in an imaginative way compare with just copying the existing concept this result during the post-test it only shows that Augmented Reality has the potential to enhance the creativity of the respondents and let them think out of the box to figure out or come up with the new idea in an innovative way using Augmented Reality.

Table 2. Pre-test and Post-test Performance Score of the Student in Augmented Reality Group as to Creative Thinking Skills in terms of Analytical Thinking Skills

SCORE	Pre-Test		Post-Test		Interpretation
	F	%	F	%	
14-16	--	--	--	--	E
12—13	--	--	14	28	G
8—11	1	2	34	68	F
4—7	48	96	2	4	M
0-3	1	2	--	--	P
Total	50	100	50	100	

Legend: 14-16 – Excellent (E), 12-13 – Good (G), 8-11 – Fair (F), 4-7 – Marginal (M), 0-3 – Poor (P)

Table 2 shows the pre –test and post – test using Augmented Reality under Analytical Thinking which shows development in the students' task performance. The result show that majority of the respondents during pre – test have the frequency of 48 or 96 % with a verbal interpretation of "Marginal" which implies a lower or minimal level of analytical thinking where respondents find it difficult to look over or dissect material or data in order to gain a better understanding of it. complex information or situations while after the post – test using the Augmented Reality the respondents have the frequency of 34 or 68% with a verbal interpretation of "Fair" which mean that the respondent demonstrate a moderate level of analytical skill they can evaluate and analyse information to some level, they apply analytical abilities consistently or efficiently across different contexts compare to "Marginal" and 14 or 28% with a verbal interpretation of "Good" which means that it is more proficient or demonstrated remarkable critical thinking abilities by recognizing important information, seeing trends, and coming up with workable solutions which shows during the activity that they pay attention to detail and thoroughly analyse what is happening so that they can came up into a creative and effective solutions to problems presented with this result during the post – test that the respondents have the potential to develop their analytical thinking.

Table 3. Pre-test and Post-test Performance Score of the Student in Augmented Reality Group as to Creative Thinking Skills in terms of Problem Solving

SCORE	Pre-Test		Post-Test		Interpretation
	F	%	F	%	
21-24	--	--	5	10	E
16-20	--	--	22	44	G
12—15	--	--	16	32	F
6—11	50	100	7	14	NI
0-5	--	--	--	--	P
Total	50	100	50	100	

Legend: 21-24 – Excellent (E), 16-20 – Good (G), 12-15 – Fair (F), 6-11 – Needs Improvement (NI), 0-5 – Poor (P)

Table 3 shows the pre –test and post – test using Augmented Reality under Problem Solving which shows development in the task performance of the respondents. The result show that the highest frequency of 50 or 100 % during the pre – test with a verbal interpretation of "Needs Improvement" which means that the level of the performance of the respondents is lacking in problem solving skills which needs enhancement to develop in this skills with that the result of the post – test which have the highest frequency of 22 or 44% with a verbal interpretation of "Good" which implies that the individual is able to solve problems effectively and competently, meeting or exceeding the expected standard for problem-solving skills and 5 or 10% with a verbal interpretation of "Excellent" indicates the highest level of proficiency that the respondents is exceptionally skilled at solving problems, demonstrating a deep understanding of the problems involved and consistently producing outstanding solutions with this result it shows that it has a positive impact on the problem solving of the respondents as the evidence show an increase in the percentage of the respondents having a good and excellent scores as the respondents were taught and have the idea on how to solve the problem given by the researcher which helps them to solve and .analyse the problem correctly, examples are given for guide before answering each problem in the activity.

Table 4. Pre-test and Post-test Performance Score of the Student in Simulation Group as to Creative Thinking Skills in terms of Creativeness

SCORE	Pre-Test		Post-Test		Interpretation
	F	%	F	%	
14-16	--	--	16	32	VC
12—13	--	--	21	42	C
8—11	--	--	12	24	O
4—7	50	100	1	2	I
0-3	--	--	--	--	P
Total	50	100	50	100	

Legend: 14-16 – Very Creative (VC), 12-13 – Creative (C), 8-11 – Ordinary (O), 4-7 – Imitative (I), 0-3 – Poor (P)

Table 4 shows the result of the pre – test and post – test of the students using Simulation under Creativeness which shows development in the task performance of the respondents. The result shows that the highest frequency of 50 or 100 % with a verbal interpretation of "Imitative" is where the majority of the respondents fell which means that the respondents in terms of their creativeness their works are merely imitating or duplicating existing ideas that are presented while during the post –test of the respondents the highest frequency are 21 or 42% with a verbal interpretation of "Creative" which means that the students can produce new and original concept of ideas in an imaginative way compare with just copying the existing concept this result and a frequency of 16 or 32% with a verbal interpretation of "Very Creative" implies a high level of originality and innovation which the individual generate novel idea in demonstrating a capacity for imaginative and inventive thinking as the students using Simulation as teaching tool the researcher observed that the respondents came up into their original representation of the result of the activity they add up information and detail that best describe their works.

Table 5. Pre-test and Post-test Performance Score of the Student in Simulation Group as to Creative Thinking Skills in terms of Analytical Thinking Skills

SCORE	Pre-Test		Post-Test		Interpretation
	F	%	F	%	
14-16	--	--	18	36	E
12—13	--	--	15	30	G
8—11	1	2	15	30	F
4—7	48	96	2	4	M
0-3	1	2	--	--	P
Total	50	100	50	100	

Legend: 14-16 – Excellent (E), 12-13 – Good (G), 8-11 – Fair (F), 4-7 – Marginal (M), 0-3 – Poor (P)

Table 5 shows the result of the pre – test and post – test of the students using Simulation under Analytical Thinking which shows development in the task performance of the respondents. The result shows that highest frequency of 48 or 96 % with a verbal interpretation of "Marginal" which implies a lower or minimal level of analytical thinking where respondents struggled to effectively analyze complex information or situations is where the majority of the respondents fell as what have been observe the respondents cannot analyze the information that it need to be reconstruct for them and repeatedly explain what should they need to do and answer while during the post –test of the respondents the highest frequency are 18 or 36% with a verbal interpretation of "Excellent" in analytical thinking skills which implies a very high level of analytical thinking that the individual can analyze complex situations or problems adeptly, draw insightful conclusions, and generate advanced solutions and a frequency of 15 or 30% with a verbal interpretation of "Good" analytical thinking skills of the respondents indicating that the individual can analyze situations or problems effectively, with this results it only shows that the respondents shows an improvement and Simulation had a positive impact on analytical thinking skills of the respondents by achieving the "Excellent" and "Good" scores.

Table 6. Pre-test and Post-test Performance Score of the Student in Simulation Group as to Creative Thinking Skills in terms of Problem Solving

SCORE	Pre-Test		Post-Test		Interpretation
	F	%	F	%	
21-24	--	--	24	48	E
16-20	--	--	17	34	G
12--15	--	--	8	16	F
6--11	50	100	1	2	NI
0-5	--	--	--	--	P
Total	50	100	50	100	

Legend: 21-24 – Excellent (E), 16-20 – Good (G), 12-15 – Fair (F), 6-11 – Needs improvement (NI), 0-5 – Poor (P)

Table 6 shows the result of the pre – test and post – test of the students using Simulation under Analytical Thinking which shows a significant development in the task performance of the respondents. The results shows that during the pre – test the highest frequency is on the 6-11 score scale with a frequency of 50 or 100 % with a verbal interpretation of "Needs Improvement" in problem solving where the majority of the respondents is which implies that the level of the performance of the respondents is below the expected standard which needs enhancement to develop in this skills, while during the post – test the 21-24 score scale got the highest frequency of 24 or 48 % with a verbal interpretation of "Excellent" in problem solving indicates the highest level of proficiency that the respondents can quickly understand a problem, think through possible solutions, and implement the best one effectively demonstrating a deep understanding of the problems involved and consistently producing outstanding solutions with this result and also the frequency of 17 or 34 % with the verbal interpretation of "Good" in problem solving which implies that hat the individual is able to solve problems effectively and competently, meeting or exceeding the expected standard for problem-solving skills which shows that Simulation had a positive impact in the enhancement of the respondents problem solving skill which is evident by the increase of the percentage of the respondents scores as the respondents during the activity shows that they can evaluate, remember and understand the concept in each problem that when they solve each problem they use it as a guide so that they can get the correct amount of element that is need in each experiment.

Table 7. Pre-test and Post-test Task Performance Score of the Student as to Augmented Reality Teaching Tool

Creative Thinking Skills		Pre-Test		Post-Test		t-value	df	p-value	Interpretation
		Mean	SD	Mean	SD				
Creativeness		4.28	1.07	9.16	2.02	16.7	49	<.001	Significant
Analytical		4.2	0.83	9.44	1.94	20.6	49	<.001	Significant
problem solving		6.72	1.33	14.68	3.76	14.5	49	<.001	Significant

Table 7 shows significant difference between the pre-test and post-test task performance scores of respondents in terms of creative thinking skills using Augmented Reality. Based on the table, the mean score indicates an increase when compared to the respondent's pre- and post-test, resulting a statistically significant t – value and a p-value of <.001 in all the indicators under "Creative Thinking Skills", indicating a significant difference in the respondent's "Creative Thinking Skills" when using augmented reality.

As the students used the Augmented Reality the researcher observed that they find the activities satisfying by experiencing laboratory activities that incorporate to the real world even though they did not perform it in the actual laboratory. There are times that the respondents is more focused on the technology itself rather than the learning objectives that there are times that they explore it more than focusing on the activity as to address this kind of situation the researcher assign leaders and responsible member to monitor and constantly remind each respondents what to do to let them finish the activity and with this it only shows that even there are some interruptions in using Augmented Reality as teaching there is still an improvement on the enhancement of their creative thinking skills as shown in the result.

Table 8. Pre-test and Post-test Task Performance Score of the Student as to Simulation Teaching Tool

Creative Thinking Skills		Pre-Test		Post-Test		t-value	df	p-value	Interpretation
		Mean	SD	Mean	SD				
Creativeness		4.48	0.86	11.68	2.26	19.9	49	<.001	Significant
Analytical		4.68	1.25	11.6	2.8	18.4	49	<.001	Significant
problem solving		7.36	1.48	18.56	4.2	18	49	<.001	significant

Table 8 shows the significant difference between the pre-test and post-test task performance scores of respondents in terms of Creative Thinking skills using Simulation. The result demonstrates that simulation was highly effective in improving creative thinking among the respondents. The significant increases in post-test scores compared to pre-test scores, along with the statistically significant t-values and p-values, indicate the significance and effectiveness of simulation as a teaching tool in enhancing these skills as it let the students on hands-on experience helps them improve a deeper understanding of difficult concepts that are otherwise challenging to grasp with traditional methods as well as they can simulate different experiments that not only guarantees safety but also allows for frequent trials, leading to better understanding of the activity.

The overall results shows that the used of Simulation can significantly enhance the creative thinking skills of the respondents. The respondents used Simulation as teaching tool the researcher observed that exposing them help to improve their creative thinking skills as it offer a safe environment for students to explore and experiment without the fear of failure or consequences. This encourages students to think outside the box, try different approaches, and innovate. Through engaging with these simulations, students are challenged to think critically and come up with innovative ways to solve these problems as the respondents use and manipulate the teaching tool, they easily understand the lesson and what supposed to happen and do in the said activity, they become curious on what is going to happen next.

Table 9. Post-test Task Performance Score of the Students on Creative Thinking Skills when exposed to Augmented Reality and Simulation as Teaching Tools

Creative Thinking Skills		Augmented		Simulation		t-value	df	p-value	Interpretation
		Mean	SD	Mean	SD				
Creativeness		9.16	2.02	11.7	2.26	5.87	98	<.001	Significant
Analytical		9.44	1.94	11.6	2.8	4.48	98	<.001	Significant
Problem solving		14.68	3.76	18.6	4.2	4.87	98	<.001	Significant

Table 9 presents the comparison of the post – test task performance scores of the respondents on Creative Thinking Skills when they are exposed to different teaching tools, specifically Augmented Reality and Simulation. The results demonstrates that Simulation was significantly more effective than Augmented Reality (AR) in enhancing creative thinking skills, specifically in terms of creativeness, analytical thinking, and problem-solving it result shows that the t-values for all three skills are significant, indicating that the differences between the effects of Simulation and Augmented Reality are not due to random chance. This suggests that Simulation is considerably better teaching tool than Augmented Reality for enhancing creative thinking skills,

as supported by the significant differences in performance between the two teaching tools which shows a significant increase from there mean scores as well.

During the actual used of the Augmented Reality and Simulation the students have difficulty in focusing using the Augmented Reality as they are exploring the technology itself rather than focusing on the activity that are assign to do in the teaching tool that make their time shorter to conduct the activity. Meanwhile those respondents who use the Simulation said that they enjoy using and manipulating it as the respondents is provided an interactive and hands on activity and experience that made them engage in the activity and make collaboration with other students that also help to enhance their learning experiences which make it more enjoyable for them, it is also easier for them to put and make the solutions that are needed the activity and as for the researcher observation they really have the best time in using the Simulation even just giving the instruction one time they already know what to do and based on their out puts they really improve in their Creative Thinking Skills. The respondents have the time to explore more of the activity as they finish the experiment. It also help to catch the attention of the students because they experience it on their own and not just imagining or watching on the video what will happen they can easily say that the experiment is cool and they were amaze that even without a laboratory they can experience lab work and be safe both at the same time with the help of simulation, although both of them help the student and make learning fun and safe, simulation as a teaching tool standout to be the best in promoting creative thinking skills. As simulation provide immediate and detail information as to Augmented Reality that it takes time to show the result so the time become shorter in redoing the activity moreover when the samples are not place properly. Simulation also provide more hands on learning experiences as the students can explore more on simulation while in Augmented Reality also provide hands on learning but is limited although it is immersive.

Conclusion

Based on the findings of this study, the following conclusions are drawn:

There is a significant difference between the pre-test and post –test task performance score of the respondents as to Augmented Reality and Simulation; hence the null hypothesis posited in the study is not sustained.

There is a significant difference on the post – test task performance score on Creative thinking skills of grade 8 students in Science when exposed to the teaching tool as to creativeness, analytical thinking and problem solving thus the null hypothesis is not sustained.

References:

Research Papers:

1. Arici, Yildirim, Caliklar, & Yilmaz, 2019 Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis https://www.researchgate.net/publication/335078159_Research_trends_in_the_use_of_ augmented_ reality_in_science_education_Content_and_bibliometric_mapping_analysis American Association for the Advancement of Science. (2018). Vision and change in undergraduate biology education: Uniting research and practice. https://visionandchange.org/

2. Astutik, S., & Prahani, B. K. (2018). The practicality and effectiveness of Collaborative Creativity Learning (CCL) model by using phet simulation to increase students' scientific creativity. International Journal of Instruction, 11(4), 409–424. Https://doi.org/10.12973/iji.2018.11426a Retrieved from https://files.eric.ed.gov/fulltext/EJ1331043.pdf

3. Bower, M., Howe, C., mccredie, N., Robinson, A., Grover, D.: Augmented reality in education–cases, places and potentials. Educational Media International 51(1), 1–15 (2014)Retrieved from https://inria.hal.science/hal-03686009/documentJavier, M. J., & Aliazas, J. V. (2022). Community of Inquiry Framework in Basic Science Process During Synchronous Learning Modality. International Journal of Science, Technology, Engineering and Mathematics, 2(4), 92-113.

4. Cerqueira, C. S., & Kirner, C. (2012). Developing Educational Applications with a Non-Programming Augmented Reality Authoring Tool. Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications (pp. 2816-2825).Retrieved from https://pdfs.semanticscholar.org/11c7/7089b13d02cf069fa0c665474fe34239b858.pdfPhilippine Congress. (2013). Republic Act No. 10533: An Act Enhancing the Philippine Basic Education System by Strengthening Its Curriculum and Increasing the Number of Years for Basic Education, Appropriating Funds Therefor and for Other Purposes. Retrieved from https://www.officialgazette.gov.ph/2013/05/15/republic-act-no-10533/

5. Droui, M., & El Hajjami, A. (2014). Simulations informatiques en enseignement des sciences: apports et limites. Epinet: Revue Électronique de l'epi, 1–17. Http://www.epi.asso.fr/revue/articles/a1404e.htmRetrieved from https://files.eric.ed.gov/ fulltext/EJ1331043.pdf Department of Education. (2016). DepEd Order No. 35, s. 2016: Policy Guidelines on the Implementation of the Learning Action Cell (LAC) as a K–12 Basic Education Program School-Based Continuing Professional Development Strategy for the Improvement of Teaching and Learning. Manila, Philippines

6. Radu, I. Why should my students use AR? A comparative review of the educational impacts of augmented-Reality. In Proceedings of the 2012 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), Atlanta, GA, USA, 5–8 November 2012. Retrieved from https://pdfs.semanticscholar.org/cbea/5bb251c0de20a34e585bb89e0003c2e4cabf.pdf

7. Shapley, K., Sheehan, D., Maloney, C., & Caranikas-Walker, F. (2011). Effects of technology Immersion on Middle School Students' Learning Opportunities and Achievement. The Journal Educational Research, 104, 299-315. Http://dx.doi.org/10.1080/ 00220671003767615 Retrieved from https://pdfs.semanticscholar.org/11c7/7089b13d02cf069fa0c665474fe34239b858.pdf

8. Smith, J., Jones, M., & Brown, K. (2017). Enhancing creativity through simulation-based learning. Journal of Creativity in Education, 2(1), 45-56. https://journals.sagepub.com/doi/10.3102/0034654320933544National Research Council. (2015). Science teachers' learning: Enhancing opportunities, creating supportive contexts. The National Academies Press