STEAM Education Using Design Thinking Process Through Virtual Communities of Practice (STEAM-DT-VCoPs)

Thiti Jantakun

Department of Computer Education, Faculty of Education

Roi Et Rajabhat University, Roi Et, Thailand

Tel: 66-894-186-231 E-mail: thiti100@gmail.com

Kitsadaporn Jantakun

Department of Computer Education, Faculty of Education

Roi Et Rajabhat University, Roi Et, Thailand

Tel: 66-910-618-359 E-mail: jansri.kp@gmail.com

Thada Jantakoon (Corresponding author)

Department of Computer Science, Faculty of Science and Technology

Rajabhat Maha Sarakham University, Maha Sarakham, Thailand

Tel: 66-961-694-277 E-mail: thada.phd@gmail.com

Received: March 15, 2021 Accepted: April 13, 2021 Published: April 23, 2021

doi:10.5296/jei.v7i1.18420 URL: https://doi.org/10.5296/jei.v7i1.18420

Abstract

These objectives of the study are 1) to design STEAM education using Design Thinking Process through Virtual Communities of Practice (STEAM-DT-VCoPs), and 2) to evaluate the designed STEAM-DT-VCoPs. It divides the research procedures into two phases. The first phase is to design STEAM-DT-VCoPs, and the second phase is to evaluate the STEAM-DT-VCoPs. The sample group of this study comprises fourteen experts selected by purposive sampling. The arithmetic mean and standard deviation analyzed data. The research findings are: 1) The STEAM-DT-VCoPs comprise three steps are 1.1) the role of virtual communities of STEAM practice 1.2) Design Thinking Process through Virtual Communities of Practice, and 1.3) the various disciplines in STEAM education. 2) The experts agree that STEAM-DT-VCoPs is the highest level of appropriateness.

Keywords: STEAM education, Design Thinking, Virtual Communities of Practice, Virtual teams, STEAM-DTVCoPs

1. Introduction

STEAM (Science, Technology, Engineering, Arts, and Mathematics) curriculum integrates the arts and STEM subjects to enhance student participation, imagination, innovation, problem-solving skills, and other cognitive benefits (Liao, 2016), and employability skills required for career and economic development (Colucci-Gray et al., 2017).

Design Thinking (DT) is a user-centered approach to creativity, design, and development that prioritizes the exploration and observation of human needs (Gruber et al., 2015). A series of iterative activities are included in DT, including an initial collection of exploratory activities focusing on collecting data to define user needs, defining the problem, identifying the problem parameters, and then coming up with solutions, which are prototyped and checked. For its ability to promote creativity across a wide variety of organizations and concerns, DT is currently receiving unparalleled interest from practitioners and gaining increased attention from researchers.

One of the most common uses of a CoP is in learning societies, which is especially important for university systems. Virtual Communities of Practice (VCoPs) in the postsecondary learning environment will support students and professors at the college level. Cross-cultural experiences and technology-enhanced learning are two facets of Web 2.0 technologies that may help students succeed in school. More students may engage in experiments or other "hands-on" implementations of what they are studying thanks to VCoPs. Web 2.0 could help researchers communicate more effectively. CoPs at the postsecondary level have valuable experiential learning experiences, such as student study projects. This professor-student partnership not only promotes information dissemination within their CoP, but it also produces a byproduct that can be utilized by other cultures. Researchers can do more in a simulated environment. They benefit from shorter travel times, tighter feedback loops, and more readily available information.

This research looked at STEAM education through Virtual Communities of Practice (STEAM-DT-VCoPs) to see what, if any, steps STEAM-DT-VCoPs take in general practice training. Furthermore, based on the study, this development establishes evidence-based recommendations for using STEAM-DT-VCoPs, which could be used to inform implementation of general practice training.

2. Literature Review

2.1 STEAM Education

The term STEAM (Science, Technology, Engineering, Arts, and Mathematics) is used to describe the concept of STEAM. The STEAM definition is described in a number of ways after this point. Four major forms of disciplinary integration emerged from the papers reviewed: Trans disciplinary, interdisciplinary, multi-disciplinary, and cross-disciplinary (Marshall, 2014). STEAM education involves fully incorporated disciplines with no limits, as well as lessons based on real-world issues or inquiries (Quigley et al., 2017). STEAM education that is interdisciplinary brings together many disciplines around a common theme, but each discipline remains distinct (Thuneberg et al., 2017). Integration between two or more disciplines is included in multidisciplinary STEAM, but they are not combined (Payton, White, & Mullins, 2017). Finally, cross-disciplinary STEAM education focuses on looking at one discipline through the eyes of another, such as music physics (Gates, 2017). Furthermore, the writers disagree as to whether STEAM completely incorporates the five discipline areas or only partly integrates two or three disciplines. One example of a partially combined STEAM (technology and art) activity used melted glass (in an artist's glass studio) to educate students about the science of volcanoes. Because of the similar properties, hardening, and crystallizing processes, the glass was used as a metaphor for volcanic lava (Gates, 2017). This partially incorporated STEAM lesson merged glass making with geoscience, omitting the STEAM acronym's technology, engineering, and mathematic disciplines. Another article (Smith & Paré, 2016) described a partially integrated STEAM activity in which students used mathematics and pottery to create a Klein bottle. While the authors explored how science, technology, and engineering could be incorporated into the project, the article itself focused solely on the mathematics and pottery aspects of the Klein bottle making process. It's worth remembering that this was not a structured STEAM lesson for pupils, but rather a curiosity exercise between a math and an art instructor.

2.2 Design Thinking Integrate STEAM

The word "Design Thinking" refers to the cognitive processes and thinking skills that designers use in their work (Watson, 2015). There are numerous Design Thinking models available in the market, the majority of which have areas of overlap or similarity in themes. And as there is no one best way to approach Design Thinking, it comes down to exploring and choosing a model that fits well. Design Thinking has increasingly been discussed and used to integrate STEAM into more engineering domains, but it also stands by itself as a framework for thinking and problem-solving that spans the arts and sciences. Engineers may use Design Thinking, but so may visual artists (Boy, 2013; Brophy et al., 2008). The Stanford design model created within the Stanford School of Design is one of the most common, well-known, and well-established Design Thinking models (Plattner et al., 2015). This was the guiding model that our teachers used to reconsider their curriculum in STEAM-based ways, so we've included a review of it below. The Stanford model has five Design Thinking phases or stages, also known as modes, that are worked through to arrive at a problem solution or resolution. Empathize, describe, ideate, prototype, and evaluate are the five modes. Design Thinking is an iterative process, despite the fact that we define it in a linear manner (Plattner, Meinel, & Leifer, 2010). To understand or explore issues and solutions, designers, students, and others may loop through the process or reenter modes as required.

2.3 Virtual Communities of Practice within STEM

There is a fundamental breakdown in bridging the difference between study and practice in STEM practice and STEM education (Lewis et al., 2011). Virtual Communities of Practice have been shown to be especially successful in STEM disciplines, where the division between researchers and practitioners has traditionally been quite distinct (Lewis et al., 2011). The willingness of these two agents to interact and share their experience and analysis within the realms of Web 2.0 technologies is unrivaled (Wenger, 2002). One of the main obstacles researchers face in being more active in communities of practice is their very limited agendas (Lewis et al., 2011). Personal collaboration becomes difficult to handle as a result of this. Mutually beneficial research cannot be shared without this interpersonal contact, and the research process is severely hampered. The presence of Web 2.0 will significantly reduce this particular barrier within the STEM research realm (Lewis et al., 2011). The creation of flexible "social networking" platforms can be used to link academics, teachers, students, and practitioners in previously unimaginable ways (Wenger, 2002).

3. Method

This study was divided into two phases which are (1) The study that related to theories, research and experts' opinion, (2) Evaluation on the STEAM-DT-VCoPs.

3.1 Phase 1: The Study That Related to Theories, Research, and Experts' Opinion

The study in this phase included the study of theories and research on the STEAM education to be used as guidelines in determining learning processes and components of the model. The model will be designed after documentation review, and then the interview will be conducted to get an opinion towards the model from fourteen experts.

3.2 Phase 2: Evaluation on the STEAM-DT-VCoPs

After gathering all of information and modifying the STEAM-DT-VCoPs, five STEAM education experts, five Design Thinking experts, and four communities of practice experts were selected to evaluate the model by using five scales model evaluation form. The expert selection criteria consisted of (1) the experts must have more than three years of experiences in the STEAM education/Design Thinking field/communities of practice, (2) the experts must have a related work in STEAM education/Design Thinking field/communities of practice, and (3) the experts must have experiences in designing or teaching with undergraduate students.

4. Results

The study's findings in terms of theories, analysis, and expert opinion. Figure 1 shows the STEAM-DT-VCoPs.

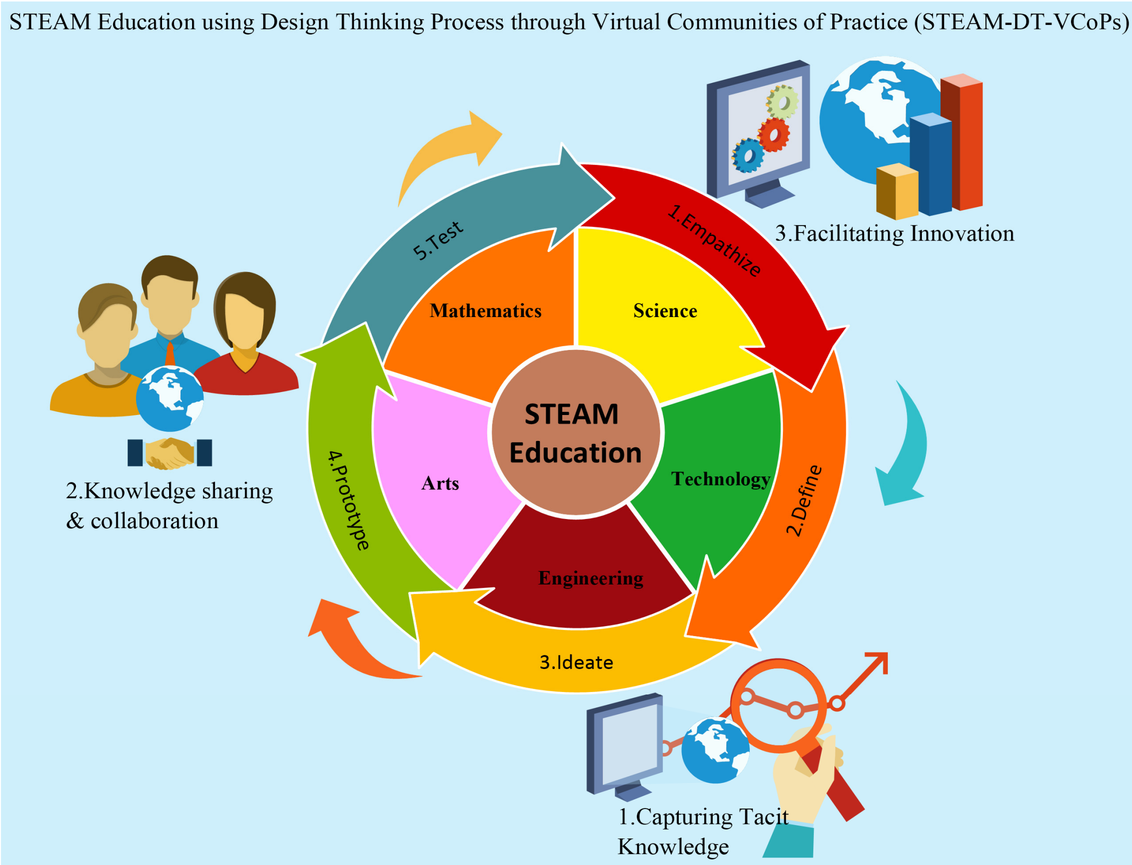

Figure 1. STEAM-DT-VCoPs

4.1 The Role of Virtual Communities of STEAM Practice

"Groups of professionals brought together by mutual interests and common concerns about participation, exchange, trading, organizing, and management of their tacit and explicit expertise in order to enhance their professional performance, as well as the performance of their organizations as a whole," according to the definition of Virtual Communities of Practice. Self-regulation is a feature of these cultures. They depend on the Internet's virtual space, as well as social Web 2.0 resources such as social networks. Overcoming some of the most significant obstacles faced by conventional KM networks is one of the most popular applications of Virtual Communities of Practice, as follows:

4.1.1 Capturing Tacit Knowledge

Traditional knowledge management (KM) techniques assist in the capture of explicit knowledge from an expert or a single source of experience. Web 2.00 resources go even further, allowing participants in virtual networks of clinical practice to exchange implicit information, or knowledge that is most relevant or newsworthy (Richards, 2009). The discussion and interaction among individuals serving in the organization is one of the most well-known methods for the management of tacit information. In this regard, Virtual Communities of Practice that use Web 2.0 are observed to promote dialogue through social interactions. Wiki, for example, allows several people with different fields of knowledge to socially connect and collaborate to accomplish a shared goal. As a result, it is reasonable to conclude that the use of Web 2.0 tools in the sense of Virtual Communities of Practice will address one of the most significant KM challenges: dealing with tacit awareness (Wegner, 2006; Nath, 2012).

4.1.2 Knowledge Sharing & Collaboration

One of the most important obstacles to the introduction of KM in organizations is the need for cross-functional collaboration and information sharing. In this regard, it's worth noting that information sharing entails not just the actual transfer of knowledge from one location to another, but also the sharing of social interactions during the exchange of knowledge. On the one hand, conventional KM methods do not assist in achieving the desired degree of collaboration and sharing of diverse information, skills, and ideas (Kang, Morris, & Snell, 2008). Digital communities of practice focused on Web 2.0 tools, on the other hand, aid in the exchange of different ways and media of information and knowledge, such as in media sharing services. Thanks to resources like Wiki, these communities also provide excellent opportunities for KM collaboration.

4.1.3 Facilitating Innovation

Effective knowledge management necessitates the growth of creativity and modernization by promoting the production of tacit knowledge to solve challenges that employees and the company face. As a result, KM necessitates not only information sharing, but also the application of knowledge to create new products through collaborative thought. In this regard, conventional approaches to knowledge management (KM) do not promote the use of knowledge, especially tacit knowledge, to encourage access to novel problem-solving solutions (Nath, 2012). Web 2.0 tools based Virtual Communities of Practice, on the contrary, take advantage of the collective intelligence and assembly knowledge principles; upon which Web 2.0 tools depend in the provision of innovative solutions to the problems faced by the organization, and facilitate, at the same time, the task of creating much of the applied knowledge that can benefit the organization.

4.2 Design Thinking Process Through Virtual Communities of Practice

Design Thinking was discovered to have five key phases (Plattner, 2015). This was the guiding model that our teachers used to rethink their curriculum in STEAM-based ways, so we've included a summary of it below.

(1) Empathize is the first mode. Empathy is the cornerstone of human-centered design and a necessary starting point for every design project (Plattner et al., 2010). Designers in this mode observe users and their habits, engage with and interview them, and attempt to immerse themselves in the user's experience and viewpoint. To understand their thoughts, ideas, and explanations for conduct, one may ask questions, listen to stories and experiences, observe their interactions, or explore their environment. Designers will now tackle the rest of the develop process with a better understanding of the context and issue. Many design models begin the design process with problem identification.

(2) Designers use the knowledge gained from empathizing to concentrate in on the problem in the second mode, describe mode. They deliberately go beyond a simplistic description by describing the users, problem's, and context's complexities. The solution to the problem is determined by how the problem is described. In this mode, designers express a problem statement based on the experience they've learned so far. They help to focus and frame the issue, as well as direct future design efforts (Plattner, 2015).

(3) Ideate, the third mode, investigates a large number of solutions and concepts. The aim is to think outside of the box in order to come up with novel solutions, concepts, and approaches to the problem. Designers must be open to fresh and innovative concepts while holding the issue in mind. Deferring judgment on assessing ideas gives people a sense of independence and encourages them to produce ideas freely.

(4) Designers put their ideas into action in the fourth mode of prototype by constructing a potential prototype or model of a solution to the problem after they have created multiple ideas. Prototyping is the method of bringing ideas into motion. It's not a race to the finish line, but rather a chance to get involved and put ideas into action. A prototype may be a physical item, but it can also be a storyboard, an activity, a painting, or something else entirely.

(5) The prototype is tested with real or representative users/stakeholders in the fifth mode of research. Designers can conduct interviews with users, observe them interacting with the prototype, or use any other method to gather information for improving the solutions. Testing could reveal that the prototype needs to be refined, or that the original point of view needs to be redefined and reexamined, or that empathize mode needs to be revisited to better understand users, or that the ideate mode needs to be revisited to consider alternative solutions.

4.3 The Various Disciplines in STEAM Education

According to the findings of the study based on documents and expert opinions, the portion of STEAM education consists of five core components:

4.3.1 Science

Science is concerned with what is found in nature and how it is influenced. Biochemistry, Physics, Astronomy, Chemistry, Geosciences, Space Science, and Biochemistry (including history, existence of, principles, processes, and inquiry) (AAAS, 1993; Hodson, 2009).

4.3.2 Technology

What is human-made Technology and Society, Architecture, Abilities for a Technical Environment, The Designed World (including Medical, Agriculture & Biotechnology, Building, Manufacturing, Knowledge and Communication, Transportation, Power & Energy) (ITEA, 2000).

4.3.3 Engineering

Engineering is the application of imagination and logic, focused on mathematics and science, to make contributions to the world in the fields of aeronautics, architecture, agriculture, chemical engineering, civil engineering, computer engineering, electrical engineering, environmental engineering, fluid engineering, industrial/systems engineering, materials engineering, mechanical engineering, mining engineering, naval architecture, nuclear engineering, and ocean engineering (AAAS, 1989; ASEE, 2008; NAE, 2004).

4.3.4 Arts

How society progresses, affects, interacts, and is understood in the past, present, and future through its attitudes and customs Physical, Fine, Manual, Language, and Liberal Arts (including Sociology, Education, Politics, Philosophy, Theology, Psychology, History, and other subjects...) In the year 2000, the International Telecommunications Engineering Association (ITEA) published an article

4.3.5 Mathematics

Numbers and Operations, Algebra, Geometry, Measurement, Data Analysis &Probability, Problem Solving, Reasoning & Proof, Communication, (including Trigonometry, Calculus & Theory) (NCTM, 1989).

Table 1. The arithmetic mean and standard deviation result from fourteen experts.

List of Evaluation	**$\bar{x}$**	**S.D.**	**Level of appropriateness**
The role of virtual communities of STEAM practice			
- Capturing Tacit Knowledge	4.64	0.63	Highest
- Knowledge sharing & collaboration	4.78	0.42	Highest
- Facilitating Innovation	4.71	0.46	Highest
Design Thinking Process through Virtual Communities of Practice			
- Empathize	4.64	0.49	Highest
- Define	4.57	0.51	Highest
- Ideate	4.78	0.25	Highest
- Prototype	4.71	0.46	Highest
- Test	4.64	0.49	Highest
The various disciplines in STEAM education			
- Science	4.71	0.46	Highest
- Technology	4.64	0.49	Highest
- Engineering	4.64	0.49	Highest
- Arts	4.85	0.36	Highest
- Mathematics	4.78	0.42	Highest
Overall Score	**4.70**	**0.47**	**Highest**

Evaluation of the overall processes of the STEAM-DT-VCoPs found the mean was 4.70 and the standard deviation was 0.47. As a result, the overall processes as the highest appropriate.

5. Conclusion

The research findings show that 1) the STEAM-DT-VCoPs include three steps; the details thereof were as follow: The role of virtual communities of STEAM practice, Design Thinking Process through Virtual Communities of Practice, and the various disciplines in STEAM education and 2) the experts agree as to STEAM-DT-VCoPs was appropriateness in the highest level. To use the STEAM-DT-VCoPs, any education institutes that desire to apply these Design Thinking Process through Virtual Communities of Practice should be prepared terms of the role of virtual communities of STEAM practice, various disciplines in STEAM education. According to the assessment by experts, it was found that STEAM-DT-VCoPs was the highest level of appropriateness. The results were in accordance with Chouyluam et al. (2021) who found that which describes The five principles of the innovation process are as follows: (1) empathize is a step in which you must consider the problems of your customers or users of innovation, (2) define is a step in which you must recognize the problems in order to find a solution, (3) ideate is a process of brainstorming and creating new ideas to implement innovation to satisfy the needs of your users of innovation, and (4) prototype is a step in which you must construct prototypes. (5) Test is the process of putting an idea to the test in real-world situations and evaluating how well it works in order to refine and enhance it to meet the needs of users and optimize benefits. Each phase will be more complicated than the last.

References

AAAS. (1989). *Science for all Americans*. Washington, DC: AAAS.

AAAS. (1993). *Benchmarks for Science Literacy*. Washington, DC: AAAS.

ASEE (2008). *Engineering: Go for it! Make a difference, change the world*. Washington, DC: American Society of Engineering Education ASEE.

Boy, G. A. (2013). From STEM to STEAM: Toward a human-centered education, creativity & learning thinking. *Proceedings of the 31st European conference on cognitive ergonomics*. New York: ACM. https://doi.org/10.1145/2501907.2501934

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education, 97*(3), 369-387. https://doi.org/10.1002/j.2168-9830.2008.tb00985.x

Chouyluam, S., Wannapiroon, P., & Nilsook, P. (2021). Creative Design Thinking Learning Model Integrated Immersive Experiential Marketing to Enhance Digital Entrepreneurs. *International Journal of Trade, Economics and Finance, 12*(1), 26-32. https://doi.org/10.18178/ijtef.2021.12.1.689

Colucci-Gray, L., Trowsdale, J., Cooke, C. F., Davies, R., Burnard, P., & Gray, D. S. (2017). *Reviewing the potential and challenges of developing STEAM education through creative* *pedagogies for 21st learning: How can school curricula be broadened towards a more responsive, dynamic, and inclusive form of education?* British Educational Research Association.

Gates, A. E. (2017). Benefits of a STEAM collaboration in Newark, New Jersey: Volcano simulation through a glass-making experience. *Journal of Geoscience Education, 65*(1), 4-11. https://doi.org/10.5408/16-188.1

Gruber, M., de Leon, N., George, G., & Thompson, P. (2015). Managing by Design. *Academy of Management Journal, 58*(1), 1-7. https://doi.org/10.5465/amj.2015.4001

Hodson, D. (2009). Teaching and learning about science. *Language, theories, methods, history, traditions and values*. Rotterdam: Sense Publishers. https://doi.org/10.1163/9789460910531

ITEA (International Technology Education Association). (2000). *Standards for technological literacy: Content for the study of technology*. Reston VA: International Technology Education Association.

Kang, S., Morris, S. S., & Snell, S. A. (2008). Relational archetypes, organizational learning, and value creation: Extending the human resource architecture. *Academy of Management Review, 32*, 236-256. https://doi.org/10.5465/amr.2007.23464060

Lewis, L. A., Koston, Z., Quartley, M., & Adsit, J. (2011). Virtual Communities of Practice: Bridging research and practice using Web 2.0. *Journal of Educational Technology Systems, 39*, 151-161. https://doi.org/10.2190/ET.39.2.e

Liao, C. (2016). From interdisciplinary to transdisciplinary: An arts-integrated approach to STEAM education. *Art Education, 69*(6), 44-49. https://doi.org/10.1080/00043125.2016.1224873

Marshall, J. (2014). Transdisciplinarity and art integration: Toward a new understanding of art-based learning across the curriculum. *Studies in Art Education, 55*(2), 104-127. https://doi.org/10.1080/00393541.2014.11518922

NAE. (2004). *Educating the engineer of 2020: Visions of engineering in the new century*. Wshington, D.C. The National Academies Press.

Payton, F. C., White, A., & Mullins, T. (2017). STEM majors, art thinkers-issues of duality, rigor and inclusion. Journal of STEM Education: *Innovations and Research, 18*(3), 39-47.

Plattner, H., Meinel, C., & Leifer, L. (2015). Design Thinking research. *Building innovators*. Cham: Springer. https://doi.org/10.1007/978-3-319-06823-7

Plattner, H., Meinel, C., & Leifer, L. (2010). *Design Thinking: Understand-improve-apply*. Berlin, Germany: Springer Science & Business Media.

Quigley, C. F., Herro, D., & Jamil, F. M. (2017). Developing a conceptual model of STEAM teaching practices. *School Science and Mathematics, 117*(1-2), 1-12. https://doi.org/10.1111/ssm.12201

Richards, B. (2009). A social software/Web 2.0 approach to collaborative knowledge engineering. *Information Sciences, 179*, 2515-2523. https://doi.org/10.1016/j.ins.2009.01.031

Smith, C. E., & Pare, J. N. (2016). *Exploring klein bottles through pottery: A STEAM investigation. Mathematics Teacher, 110*(3), 208-214. https://doi.org/10.5951/mathteacher.110.3.0208

Thuneberg, H., Salmi, H., & Fenyvesi, K. (2017). Hands-on math and art exhibition promoting science attitudes and educational plans. *Education Research International, 2017*(1), 1-13. https://doi.org/10.1155/2017/9132791

Watson, A. D. (2015). Design Thinking for life. *Art Education, 68*(3), 12-18. https://doi.org/10.1080/00043125.2015.11519317

Wenger, E. (2006). *Communities of practice a brief introduction*. Retrieved January 5, 2021, form http://www.ewenger.com/theory

Wenger, E., McDermott, R. A., & Snyder, W. (2002). *Cultivating communities of practice: A guide to managing knowledge*. Boston, MA: Harvard Business School Press.

Copyright Disclaimer