Bulletin of the Technical Committee on Learning Technology (ISSN: 2306-0212), Volume 21, Number 2, June, 32-36 (2021)

Using Digital Technologies in Museum Learning Activities to Enhance Learning Experience: A Systematic Review

Shuang Chen, Anqi Duan, and Junyu Wang

***Abstract*—Technologies are used to boost learning experience in museums, and experts from various fields have joined in and collaborated to make contributions. However, the roles of stakeholders and the selection of digital tools, learning objects, and outcomes are underrepresented. To cover this gap, a systematic review using Activity Theory was conducted, where 32 studies in technology-assisted museum learning were examined. Seven dimensions including — (a) subjects (learners from different groups), (b) instrument (educational technologies and digital tools), (c) object (academic or behavior goals), (d) rules (design, implementation procedures, and performance measures), (e) community (stakeholders of museum learning activities), (f) division of labors (relevant works distributed to different roles in community during the whole process), (g) outcome (academic performance or learning behaviors) were analyzed. Furthermore, existing gaps were examined within the studies (e.g., lack of collaboration from different stakeholders), challenges (e.g., limited number of participants and faculty), and recommendations were identified and provided under each content analysis section.**

***Index Terms*—Technologies, Learning activities, Museum education, Activity Theory**

I. Introduction

The educational function of museums has been prompted by the wave of equal opportunities of learning since the 18th century and has been universally recognized after the benchmark documents published by AAM [1] and UNESCO [2], which clarified its role and public responsibilities on education. The International Council of Museums (ICOM) has also highlighted museums' "purposes of education" in its latest definition of museums [3]. Learning activities in museums are designed as structured, supportive, and student-centered non-formal learning experiences, with interdisciplinary contents based on objects in the exhibitions [4]. This has provided multiple educational opportunities and entry points to satisfy multiple instructional needs of learners, and usually foster high-level skills for the 21st century, such as critical thinking [5]. Inextricably interweaving, those elements allow the learning activities in museums to be more contextualized and authentic.

With the aim of transforming learning experiences in museum education activities, diverse digital technologies have been applied, such as Virtual Reality (VR), to increase learners' engagement and interactions with learning objects and contents, or to facilitate collaborative learning among students [6-8].

Despite that many ongoing practices and research have been conducted about using technologies for museum education, no systematic review, to the best of our knowledge, was conducted on what and how technologies have been integrated into those learning experiences. Consequently, limited information is found related to this field, as well as the associated challenges.

To close this gap, this study provides a systematic review of the use of digital technologies in museum learning activities. The purpose of this study is to provide an overview of the current research field, suggest the type of digital tools and instructional methods to use in museum education, and highlight future research directions.

The research questions of this study are as follows:

RQ1: What relevant features concerning the design, implementation, and outcome of museum learning activities using technologies can be identified through the lens of Activity Theory?

RQ2: What recommendations can be made to improve research about integrating technologies into museum learning activities?

II. Method

A. Search Strategy Process

Using PRISMA guideline [9], the systematic search focused mainly on journal papers within the Web of Science database. First, all the three researchers conducted title and abstract screening with keywords including "museum", "education", "technology", "digital tools" and so on. Studies (based on the title, abstract and full text) were excluded because: the study (a) is not an empirical study, (b) does not aim at offline museum education within physical museums, (c) does not involve human participants, and (d) does not have sufficient description of research design. Researchers first screened independently, and then the result of each screening will be checked by a different researcher; also, all divergences were discussed until the agreement is reached: the agreement ratio was around 90% first and reached 100% after discussions. Finally, a total of thirty-two studies were included. Fig. 1 presents the selection process.

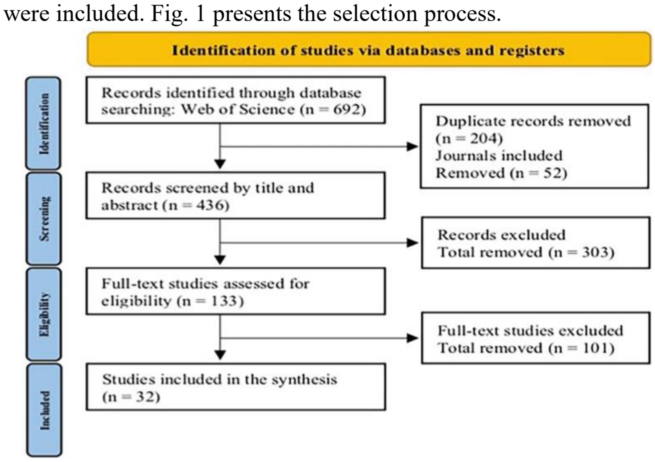

Fig. 1. Flow chart for the study search and selection process.

Received May 15, 2021, Accepted May 26, 2021, Published online June 27, 2021.

S. Chen is with the Smart Learning Institution of Beijing Normal University, Beijing, China. (Corresponding e-mail: chloe.chen0054@gmail.com).

A. Duan was with the Smart Learning Institution of Beijing Normal University, Beijing, China. (e-mail: a1duan@outlook.com).

J. Wang is with the Mathematics, Science & Technology Department, Teachers College, Columbia University, New York, USA. (e-mail: jw3989@tc.columbia.edu).

Bulletin of the Technical Committee on Learning Technology (ISSN: 2306-0212), Volume 21, Number 2, June, 32-36 (2021)

B. Data Extraction according to the Activity Theory

In this study, the Activity Theory was adopted to analyze the learning where multiple technologies have been used inside the museums in each study. Particularly, the learning in museums is defined as learning activities, for the learning happens in the form of operations and actions embedded in activities [10], including all kinds of learning activities happen in the museums, such as visiting, workshops, family tours, and curriculum [11]. The Activity Theory can be used as a philosophical and cross-disciplinary framework to understand human practices [10]. Thus, different components in learning activities (e.g., learners, learning tools, learning goals and achievements, etc.) and their relationships can be studied under this framework. In this way, the result of this review will be according to the seven dimensions in the Activity Theory (see Fig. 2). The data was extracted through the identification of seven dimensions of the learning activities each study carried out. The model shows the seven dimensions below, namely subject, instrument, object, rules, community, division of labor, and outcome.

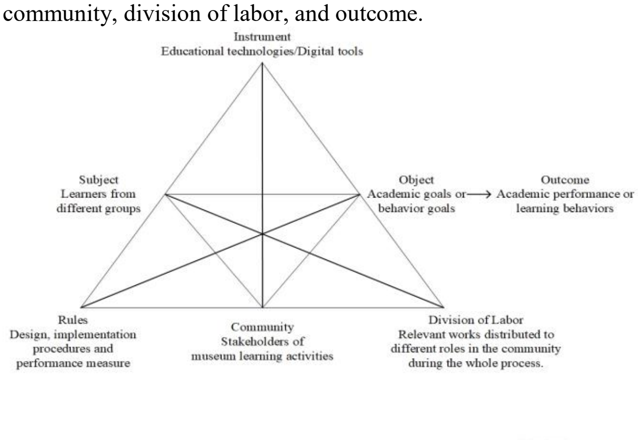

Fig. 2. Using Activity Theory to analyze technology-assisted museum learning activity studies.

III. Results And Discussion

A. Subjects

The sample size within most studies (n=22) ranged from 20 to 100. However, two of the studies only have subjects less than 20 [12-13], which may not provide enough data for solid results [14].

Considering the selection of the participants, the age range of the subject chosen by the studies was from 7 to 79 years old. Particularly, most of the subjects are from primary schools and universities.

Moreover, to instruct learning activities or eliminate effects of disturbance, the prior knowledge of participants was measured by pre-tests or investigation of learners' background in ten studies, concerning the target learning content in museums [15], the information of museums or exhibitions, or the technology or devices that would be used inside museums [14].

Recommendation:

To increase the sample size, future researchers can collaborate with several schools [16] or repeat the same experiment several times with different participants [17]. Also, to decrease the impact of prior knowledge on the experiment, the comprehension test can be used, and the impact of the prior knowledge can be clearer when analyzing the result.

B. Technology

The technology component involved various kinds of educational tools used in museums. Table 1 shows how each kind of technology was used in museum learning. Different devices assisted the usage of technology in museums; twenty-five studies adopted mobile-assisted devices, such as mobiles, iPods, tablets, or other types of interactive display screens, and three studies used computers or laptops to run the software.

TABLE I
Learning Objects and Scenarios Supported by Different Technology in Museums

Technology	Purpose	Scenario
AR/VR (n=9)	To enhance the interaction and engagement with real-world objects	Participants immersed in and interacted with the real and virtual environment to form a better understanding of the learning objects.
RFID (Radio frequency identification) technology (n=4)	To improve interactivity and participants' learning motivation and efficiency	Students used RFID readers and RFID tags to sense the objects in museums to get related information and simulate real-life scenarios; the RFID technology also helps teachers to monitor students' real-time learning progress in museums through RFID [18].
Digital database/ resources (n=13)	To increase participants' knowledge	Participants have easy access to retrieve digital information of the museum.
Robots (n=2)	To increase collaboration and interaction and participants' motivation	Participants worked in pairs and to solve challenges when building robotic models [19], or participants could interact with the robotic rover to get oriented and virtual information of objects in museums [20].
QR code (n=3)	To display comprehensive information of specimens in museums	Participants were able to get the main information and virtual images of the real-life specimens in museums through scanning QR codes [21].
Location detects (GPS) (n=2)	To enhance participants' engagement in learning tasks	Students' locations in museums are detected so that teachers can send related materials or tasks to students based on their locations [22].
Animation and games (n=6)	To provide a greater sense of interactivity and authenticity to the learners	Participants explored learning concepts by interacting with virtual models of museums' objects; they also could finish learning tasks through the designed games [16][23-24].
3D printing (n=1)	To facilitate participatory learning and enhance understanding	Children and their parents could play with different 3D printed models of the artifacts [25].

Recommendations:

Since several challenges related to educational technology in museums have been identified, some recommendations were proposed. First, different cognitive levels and characteristics of participants should be identified in advance so that the technology used can be personalized to meet various preferences or needs. Second, the training of using the target technologies before learning activities is helpful, allowing participants to be familiar with the technologies, and the usability issues should also be investigated first and to assess its impact on the experiment [26].

C. Object

The objectives of the reviewed studies were to improve learners' (a) learning outcomes, including academic skills in STEM, subjects such as climatology [27] and medicine [28], (b) social and interactive skills, and (c) interest, motivation, and attitudes. Even though a large number of studies focused on improving academic learning outcomes as well as learners' motivation or interest, few studies were dedicated to investigating learners' interactivity or social interaction (n=2).

Recommendations:

The focus should be shifted from only promoting academic skills and learning outcomes to also promote collaborative learning that focused on increasing interactions between learners. Creating more technology-assisted workshops that involve cooperation is one way that allows learners to learn from each other with the help of digital tools or technologies, making more positive impacts on the learning process and outcomes.

D. Rules

In this part, the experiment procedure and performance measures are examined.

For the experiment procedure, all the studies chosen followed clear implementation procedures [29], including (1) recruiting the participants (target learners) based on the selection criteria; (2) introducing the procedure of learning activities to participants (target learners and/or teachers); (3) designing the learning activity for the experiment; (4) implementing the learning activity with participants and (5) evaluating the learning outcome of participants based on the elaborated performance measures. Four out of thirty-two studies did not instruct participants to learn and practice the target technology formally [17][21][30-31]. Moreover, eleven studies did not involve control groups.

Seventeen out of thirty-two reviewed experiments adopted pre-assessment, and all of the experiments include post-tests. Nineteen studies used interviews and observations to do a summative assessment. Some of the studies (n=4) consider the long-term effect on the subjects' learning achievement by the second time post-test.

For the performance measures, the academic achievement was the most measured one (n=22) in the post-test, and the second was the usability and usage of the target technology (e.g., [16][21]). Some studies also focused on the learners' experience inside the museums to identify the way to enhance learning, including the motivation (e.g., [18][24]), the engagement (e.g., [13][23]), interactions (e.g., [17]), and the learning styles of participants (e.g., [18][26]).

Recommendations:

Researchers could recruit more participants to set control groups with different conditions, remove the interferences, and find more support for the results. Then, researchers should design the post-test that assesses the retention of learning outcomes, and the test result can be collected online.

E. Community

The community component includes learners, teachers/instructors, parents, museum staff, subject matter experts, and research and design professionals. Most of the reviewed studies involved students as participants (n=25), and only six studies had other people as participants, such as randomly chosen visitors, local aboriginal elders, outside collaborators, and teachers or experts [23]. There were twenty-two reviewed studies involving research and design professionals, namely researchers, research associates, designers, technicians, and project managers. Twenty studies included teachers or class tutors for participants in the learning environments. One-third of the studies (n=11) involved museum staff, and three studies invited subject matter experts in the learning activities in museums. Only one reviewed study had parents involved, and one study had interpreters joined to communicate with various participants with different language backgrounds.

Recommendations:

To achieve pedagogical transformation through the integration of technologies, it is necessary to involve more subject matter experts and museum educators in the design of innovative learning activities for better learning outcomes. Second, to keep a safe learning environment in museums, schoolchildren's parents should know what would happen in activities, and it is better to have them involved in the learning process with children.

F. Division of Labor

The Division of Labor was among (a) learners, (b) staffs and partners at museums, such as museum docents, photographers, and artists, designers, and craftsmen, and (c) teachers, field experts, and educational professionals. Their roles played in the examined studies are elaborated as follows. Learners participated in (a) taking assessments that tested their prior knowledge, (b) learning fundamental knowledge, (c) participating in experiments, and (d) providing feedbacks through tests or interviews. Staffs and partners at museums (a) collaborated to design the learning activities, (b) guided or instruct students during the visit and workshop, and (c) coordinated a suitable date and time of the experiment with the school and researchers. Teachers, field experts, and educational professionals (a) selected learning target and designed learning activities, (b) designed assessments to evaluate the learning effectiveness, (c) provided fundamental knowledge teaching, (d) monitored students' progress and gave counseling, (e) facilitated in-class experience and (f) conducted the assessment of the experiment.

Recommendation:

As technology has become an indispensable part of education in museums, the role, mindset, and pedagogies of teachers should be updated, and proper training should be provided meanwhile so that new approaches to educate learners can be adopted. Concerning the activity design, teachers' recommendations should be taken into consideration to realize a comprehensive museum learning program.

G. Outcome

Three main clusters of the outcome were identified from the reviewed studies, the promoted academic performance or learning effectiveness (n=22), increased engagement, motivation, or interactions (n=20), and the positive experience using technologies (n=12). The outcome shows that the learners' acquisition of knowledge and skills are improved. Also, one-third of those studies showed the technologies indeed can enhance learning effectiveness.

Second, for studies that focused on the attitude of using technologies (n=13) and user experiences [32], most gained positive results. Furthermore, in more than half of the studies (n=20), the level of motivation or engagement is enhanced by the target technologies, and it is also concluded that technologies can provide learners better methods to learn (n=2).

Recommendation:

Despite the positive outcome above, questions are remained regarding whether museum education should generalize the use of technologies. For some learners, the experiences in museums contradict the use of digital tools [17]. To erase the resistance of the learners and fully embrace the potential to enhance learning experiences, researchers should be aware of the tension among learners, technologies, and museum learning activities, and truly transform the way of learning as well as the mindset of learners.

IV. CONCLUSION

To understand how technology is used in museum education, this systematic review explored the many empirical research implemented in museums through the perspective of Activity Theory. Seven major components of learning activities with technology in museums were analyzed, and results showed that the museum educators should integrate technologies for thorough pedagogical transformation for learners with diverse backgrounds to obtain different learning content in multiple ways.

Several limitations of this systematic review should be acknowledged. First, the review consists of a small number of studies within only one database. However, the findings provide directions for research design and implementation of technology-assisted learning in museum education, especially in ways to maximize the potential of enhancing learning using technologies. Future research may focus on making the design of learning activities in museums more align with the learning process of participants, as well as designing enough portable technologies to benefit a broader scope of subjects.

References

[1] American Association of Museums, "Excellence and Equity: Education and the Public Dimension of Museums," (AAM), Washington, DC, USA, 1992. [Online]. Available: http://ww2.aam-us.org/docs/default-source/resource-library/excellence-and-equity.pdf

[2] J. Thinesse-Demel, "Museums, libraries and cultural heritage: Democratizing culture, creating knowledge and building bridges," in *The Fifth International Conference on Adult Education.* Hamburg, Germany, 2005.

[3] International Council of Museums, "Standing Committee for Museum Definition, Prospects and Potentials (MDPP)," 2018. [Online]. Available: https://icom.museum/wp-content/uploads/2019/01/MDPP-report-and-recommendations-adopted-by-the-ICOM-EB-December-2018_EN-2.pdf

[4] H. H. Jacobs, "The growing need for interdisciplinary curriculum content," in *Interdisciplinary Curriculum: Design and Implementation*. Alexandria, VA, USA: Association for Supervision and Curriculum Development, 1989, pp. 1-11.

[5] S. Kratz and E. Merritt, "Museums and the future of education," *On the Horizon,* vol. 19, no. 3, pp. 188-195, Aug, 2011. DOI: 10.1108/10748121111163896.

[6] R. Hawkey, "Learning with digital technologies in museums, science centres and galleries," Nesta Futurelab, Bristol, UK, 2014. Available: https://www.nfer.ac.uk/publications/FUTL70/FUTL70.pdf

[7] E. P. Myrczik, "Satisfying Personal Needs at the Museum: The Role of Digital Technologies," *MedieKultur: Journal of Media and Communication Research*, vol. 30, no. 57, pp. 176-196, Dec, 2014. DOI: 10.7146/mediekultur.v30i57.16055.

[8] E. Alexandri and A. Tzanavara, "New technologies in the service of museum education," *World Transactions on Engineering and Technology Education*, vol. 12, no. 2, pp. 317-320, 2014. Available: http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.12,%20No.2%20(2014)/35-Alexandri-E.pdf

[9] M. J. Page et al., "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews," *Syst Rev*, vol. 10, no. 89, 2021. DOI: 10.1186/s13643-021-01626-4.

[10] Y. Engeström, *Learning by expanding: an activity-theoretical approach to developmental research*, 2nd ed., Cambridge, UK: Cambridge University Press, 2014.

[11] *Museum Gallery Activities: A Handbook*. American Alliance of Museums. New York, NY, USA, 2018.

[12] N. Moorhouse, M. C. tom. Dieck, and T. Jung, "An experiential view to children learning in museums with Augmented Reality," *Museum Management and Curatorship*, vol. 34, no.4, pp. 402-418, Feb, 2019, DOI: 10.1080/09647775.2019.1578991.

[13] T. Hillman, A. Weilenmann, B. Jungselius and T. Lindell, "Traces of engagement: narrative-making practices with smartphones on a museum field trip," *Learning, Media and Technology*, vol. 41, no. 2, pp. 351-370, 2016. DOI: 10.1080/17439884.2015.1064443.

[14] C. Uz Bilgin and S. Tugba Tokel, "Facilitating Contextual Vocabulary Learning in a Mobile-Supported Situated Learning Environment," *Journal of Educational Computing Research*, vol. 57, no. 4, pp. 930-953, 2018. DOI: 10.1177/0735633118779397.

[15] C. Chiu, J. Tseng and T. Hsu, "Blended context-aware ubiquitous learning in museums: environment, navigation support and system development," *Personal and Ubiquitous Computing*, vol. 21, no. 2, pp. 355-369, 2017. DOI: 10.1007/s00779-016-0986-9.

[16] P. Marty et al., "Scientific inquiry, digital literacy, and mobile computing in informal learning environments," *Learning, Media and Technology*, vol. 38, no. 4, pp. 407-428, 2013. DOI: 10.1080/17439884.2013.783596.

[17] S. Gronemann, "Portable Tablets in Science Museum Learning: Options and Obstacles," *Journal of Science Education and Technology*, vol. 26, no. 3, pp. 309-321, 2017. DOI: 10.1007/s10956-016-9680-y.

[18] C. C. Chen and C. Y. Chen, "Exploring the effect of learning styles on learning achievement in a u-Museum," *Interactive Learning Environments*, vol. 26, no. 5, pp. 1-18, Oct, 2018, DOI: 10.1080/10494820.2017.1385488.

[19] I. M. Verner at al., "A Learning Excellence Program in a Science Museum as a Pathway into Robotics," *International Journal of Engineering Education*, vol. 28, no. 3, pp. 523-533, Jan, 2012.

[20] I. Nourbakhsh, et al., "The personal exploration rover: educational assessment of a robotic exhibit for informal learning venues," *Int. J. Eng Educ.*, vol. 22, no. 4, pp. 777-791, Feb, 2006.

[21] S. Mogali, R. Vallabhajosyula, C. Ng, D. Lim, E. Ang and P. Abrahams, "Scan and Learn: Quick Response Code Enabled Museum for Mobile Learning of Anatomy and Pathology," *Anatomical Sciences Education,* vol. 12, no. 6, pp. 664-672, 2019. DOI: 10.1002/ase.1848.

[22] C. Chen and T. Huang, "Learning in a u-Museum: Developing a context-aware ubiquitous learning environment," *Computers & Education*, vol. 59, no. 3, pp. 873-883, 2012. DOI: 10.1016/j.compedu.2012.04.003.

[23] J. Rowe, E. Lobene, B. Mott and J. Lester, "Play in the museum: Design and Development of a Game-Based Learning Exhibit for Informal Science Education," *International Journal of Gaming and Computer-Mediated Simulations,* vol. 9, no. 3, pp. 96-113, 2017. DOI: 10.4018/ijgcms.2017070104.

[24] P. Zaharias, D. Michael, and Y. Chrysanthou, "Learning through Multi-touch Interfaces in Museum Exhibits: An Empirical Investigation," *Educational Technology & Society*, vol. 16, no. 3, pp. 374-384, Sep, 2013.

[25] H. Turner, G. Resch, D. Southwick, R. McEwen, A. Dubé and I. Record, "Using 3D Printing to Enhance Understanding and Engagement with Young Audiences: Lessons from Workshops in a Museum," *Curator: The Museum Journal*, vol. 60, no. 3, pp. 311-333, 2017. DOI: 10.1111/cura.12224.

[26] G. Chen, Y. Xin, and N. S. Chen, "Informal learning in science museum: development and evaluation of a mobile exhibit label system with iBeacon technology," *Education Tech Research Dev*, vol. 65, pp. 719-741, Jan, 2017, DOI: 10.1007/s11423-016-9506-x.

[27] H. Hsiao, C. Chang, C. Lin, and Y. Wang, "Weather observers: a manipulative augmented reality system for weather simulations at home, in the classroom, and at a museum," *Interactive Learning Environments,* vol. 24, no. 1, pp. 205-223, Sep, 2016. DOI: 10.1080/10494820.2013.834829.

[28] Y. Marreez, L. Willems and M. Wells, "The role of medical museums in contemporary medical education," *Anatomical Sciences Education*, vol. 3, no. 5, pp. 249-253, 2010. DOI: 10.1002/ase.168.

[29] A. Tlili, V. Lin, N. S. Chen, and R. Huang, "A Systematic Review on Robot-Assisted Special Education from the Activity Theory Perspective," *Educational Technology & Society*, vol. 23, no. 3, pp. 95-109, July, 2020.

[30] R. Alonso, J. Prieto, Ó. García and J. Corchado, "Collaborative learning via social computing," *Frontiers of Information Technology & Electronic Engineering,* vol. 20, no. 2, pp. 265-282, 2019. DOI: 10.1631/fitee.1700840.

[31] A. Alwi and E. McKay, "Experiencing museum learning through multimedia instructions," *Jurnal Teknologi*, vol. 77, no. 29, pp. 103-109, 2015. DOI: 10.11113/jt.v77.6844.

[32] P. Sommerauer and O. Müller, "Augmented reality in informal learning environments: A field experiment in a mathematics exhibition," *Computers & Education*, vol. 79, pp. 59-68, Aug, 2014, DOI: 10.1016/j.compedu.2014.07.013.

Shuang Chen earned her master's degree in Curriculum and Teaching at Teachers College, Columbia Univerisity. Her fields of interest are in curriculum design and educational technology. She is currently a researcher in Smart Learning Institution at Beijing Normal University.

Anqi Duan earned her bachelor's degree in Management Science at the University of California San Diego, and a master's degree in Learning Analytics at Teachers College, Columbia University. Her fields of interest are in English teaching and educational technology.

Junyu Wang is a master's student from Teachers College, Columbia University, New York, USA. She majors in Communication and Education at the Department of Mathematics, Science, and Technology. Her study focus is educational technology.