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RESEARCH ARTICLE

Teachers' Perceptions of the Usage of Digital Contents on Intelligent Science Lab Platform for Science Class

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ABSTRACT

The rapid advancements in digital technologies and their integration into education have reshaped teaching and learning practices, particularly in science education. Despite the increasing emphasis on digital tools like simulation content for inquiry-based learning, effectively utilizing these tools in schools remains challenging. This study aims to explore the current usage and perceptions of the intelligent science lab platform and its simulation content among science teachers, identify key factors affecting its application, and suggest strategies for improvement. The survey was conducted with 74 science teachers across elementary, middle, and high schools in South Korea, focusing on their experiences with the platform and content characteristics to investigate teachers' perceptions of intelligent science lab platform content. The collected data were analyzed using quantitative and qualitative methods to assess usage frequency, identify perceived advantages and disadvantages, and explore improvement needs. The results revealed that many teachers do not use the platform due to low usability and difficulties in lesson integration. Also, while the simulation content was recognized for its potential to support virtual science inquiry and save time, it was criticized for insufficient implementation of inquiry activities and limited realistic experiences. However, teachers emphasized the need for simulation content that is closely aligned with scientific inquiry, user-friendly, and has diverse themes and topics in this survey. Also, it can be revealed that the balance of effectiveness and efficiency for scientific activity using simulation content is the most essential factor in the development of digital content. Consequently, providing assistance with scientific inquiry, enhancing usability, and improving learning motivation is essential to increasing the digital content's effectiveness in supporting science education. Future research should further investigate the impact of digital simulation tools on student engagement and learning outcomes to refine their development and application in educational settings.

Key words : Digital contents, intelligent science lab, science education, science inquiry, simulation contents

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Introduction

Due to the rapid development of science and technology and digitalization, along with changes in the sociocultural system, human life and perception are also changing around the use of digital technology, and changes and innovations in the education system are also becoming commonplace (Vincent-Lancrin et al., 2022). In particular, to respond to the future society where it is difficult to predict changes, on·New learner competencies such as offline interaction and communication, information utilization and adaptation, and creative problem-solving skills are required. A new paradigm of expanding digital-based education is taking hold (OECD, 2022). Since the pandemic, the use of digital technologies in education has become essential, but the gap in digital competence between regions, schools, and learners is widening (Fauville et al., 2021). As a result of this phenomenon, the educational field is developing a new level of teaching and development for the effective use of digital technology. It calls for redesigning learning methods and the direct ·There is a growing awareness of and utilization of various digital content to expand indirect learning experiences (Guan et al., 2020; Reimers, 2022).

Scientific inquiry, which corresponds to a central teaching and learning method in science learning, is an experiential process that generates knowledge and acquires concepts through the process of scientific problem-solving and should be structured in the context of scientific problem-solving (Fauth et al., 2019; Yildiz & Yildiz, 2021). Therefore, it is necessary to support the learning process of experiencing the problem-solving process through the manipulation of various variables and the analysis of the results, as it can have a positive effect on the motivation of learning when learners can carry out leading activities with a degree of freedom in scientific inquiry learning using digital content (Choi & Kim, 2020). In Korea, simulation content is provided through the intelligent science lab platform to support the operation of intelligent science labs and science education, which is the national science education policy.

Hong et al. (2022) reported that the Intelligent Science Lab applies cutting-edge science and technology to cultivate scientific literacy and inquiry capabilities necessary for the intelligent information society. It is defined as an offline-linked science class space, and accordingly, it is equipped and operated with scientific inquiry, joint inquiry, immersive content, and simulation content. In addition, Han and Lim (2020) presented the principles of virtual reality-based educational simulation design, and Kim and Kim (2022) emphasized the importance of student-to-student interaction while developing a simulation-based chemistry inquiry learning program. Lee and Hong (2017) proposed the advantages and precautions of inquiry learning by developing simulations that support sediment generation reactions, and Kim et al. (2017) and Lee et al. (2018) suggested the possibility of using Python simulations in physics education. These studies expand the design and applicability of simulation content and provide various implications for improving the effectiveness of inquiry learning. However, it is not accessible enough to be easily used in schools.

In the case of science learning, many topics are challenging to explore through direct experience, such as experiments, in limited class time. Although virtual simulation content has the potential to compensate for these problems, research related to this is minimal. However, as we have seen, making cutting-edge technology readily available to teachers and expanding the learning experience of learners by improving the accessibility of digital technologies at the classroom level is a critical challenge in terms of emphasizing the nature of education (Guan et al., 2020). Therefore, in terms of expanding the experience of science learning, it is necessary to develop effective virtual simulation content that can support scientific inquiry learning and, at the same time, support learners to explore on their own and provide guidance for teachers to use it in their classroom activities effectively. It is necessary to investigate the utilization status of digital content mounted on the intelligent science laboratory platform, which is most commonly used in school sites, and analyze the characteristics of simulation content required by science teachers. Therefore, this study focused on analyzing the current usage of the intelligent science laboratory platform and the science content mounted on the platform, as well as presenting the core elements of simulation content needed by science teachers.

Theoretical Background

The education paradigm of the 21st century is located at the center of an indispensable change that requires the convergence and design of learning activities using cutting-edge technologies such as metaverse and artificial intelligence. In science education, metaverse technologies such as VR and AR provide new possibilities for education by providing spatiotemporal learning scalability in a situation where risky experiments and repeated attempts are required (Bonfield et al., 2020; WEF, 2024). In particular, the use of a variety of simulation data running in a virtual situation can increase the economics and efficiency of learning (Holmes et al., 2019), so variable manipulation and interactive content in the context of scientific inquiry learning can expand the range of media that support scientific inquiry learning. In particular, simulation content running on mobile devices can replace the parts that are difficult or impossible to implement with existing exploration activities, such as activities that are difficult to implement or execute in the science lab at the school site, experiments that are difficult to implement due to safety issues, and cases that require repetitive sampling or time-related performance and can help to derive results that are close to the actual situation (Hassan et al., 2024; Tao et al., 2024).

Public institutions mainly lead scientific simulation content developed and operated in Korea, and they are characterized by limited platforms and materials that can be used. For example, the 'Intelligent Science Lab ON' platform provides a variety of simulation materials covering all science subjects such as physics, chemistry, life science, and earth science, but the scope of use is narrow due to content focused on specific subjects or areas and limited exploration activities that make it challenging to manipulate variables. In addition, domestic content is often linked to elementary and middle school learning, focusing on immersive content (VR, AR, etc.), so there needs to be more professional content for the high school level and the development of various materials for elementary school students.

Scientific simulation content from abroad is qualitative·There are several quantitatively superior examples. The University of Colorado's PhET offers 159 simulations in a variety of areas, including physics, chemistry, earth sciences, life sciences, and mathematics. It is made to be used not only in high school but also in university lectures. In addition, PhET is enhancing its use in teaching and learning through various class materials such as class videos, instruction plans, activity sheets, and content that variables can manipulate. LabXChange provides STEAM-centric content, a courseware platform to support independent learning, and a privately operated platform allowing learners to manipulate content freely. Compared to actual use in school sites, studies that apply simulation content to science education are significantly reduced. This phenomenon is because different results are presented on the learning effectiveness of using simulation data (Jiang et al., 2022), but it is generally used in various fields in medicine and engineering because it reveals some efficient effect of learning (Liu et al., 2024; Sun et al., 2022).

Learning using digital content must consider planning, experience, and outcomes in the learning process while meeting the efficiency of learning and the suitability of digital technologies (Lee & Lim, 2018). The interaction between digital media and traditional learning methods significantly affects teaching and learning effectiveness. In addition, cognitive activity that engages learning is a key process that helps learners empathize with problem-solving situations and convert existing dictionary concepts into scientific concepts (Leuchter et al., 2014). However, despite advances in digital technology, the digital divide remains a serious problem, and since the pandemic, the disparities between regions, schools, and learners have become more pronounced (Vincent-Lancrin, 2022). In terms of the Education 4.0 paradigm, which aims to implement personalized education that is the essence of education by utilizing digital technologies, simulation content should be able to provide learners with a wide range of operational freedom and the opportunity to experience scientific activities in a virtual environment (Haderer & Ciolacu, 2022; WEF, 2024). Therefore, analyzing the core teaching and learning elements that should be included in the simulation content that can be used for scientific inquiry learning in the school field can provide essential data for developing simulation content.

Research Method

Participants

In order to investigate the current status of awareness and use of intelligent science labs and online platforms, an online survey was conducted among teachers in charge of the operation of science labs and teachers who use them among teachers in 128 intelligent science lab research schools and leading schools across the country. After reading the study's purpose and content, teachers who participated in the survey voluntarily completed the questionnaire. The results of the final 74 responses were used in the analysis, excluding teachers who did not respond to some questions and those who were not in charge of science courses (Table 1). The gender distribution of participants who answered the survey was 40 (54.1%) male and 34 (45.9%) female, and the responses of 27 elementary school teachers (36.5%), 12 middle school teachers (16.2%), and 35 high school teachers (47.3%) were used for the analysis. The average age was 40.86 years (SD: 8.64), with teachers in Gyeonggi Province and Seoul participating the most, with 17.5% and 15.0%, respectively. The rest of the regions were evenly distributed but were excluded from the analysis because there were some regional variations in the number of teachers who responded.

Table 1. The composition of participants

	Elementary School N(%)	Middle School N(%)	High School N(%)
Male	14 (18.9%)	6 (8.1%)	20 (27.0%)
Female	13 (17.6%)	6 (8.1%)	15 (20.3%)
Sum	27 (36.5%)	12 (16.2%)	35 (47.3%)

Relevant information was submitted and analyzed to determine whether teachers' attributes, such as specific majors, degrees, and educational experience, could affect the frequency of using digital content in intelligent science labs and platforms. The majors of the teachers who answered the survey were twenty-seven teachers (36.5%) in elementary education, sixteen teachers (21.6%) in physics education, fourteen teachers (18.9%) in chemistry education, ten teachers (13.5%) in biology education, seven teachers (9.5%) in earth science education, forty-three teachers (58.1%) with bachelor's degrees, twenty-nine teachers (39.2%) with master's degrees, and two teachers (2.7%) with doctoral degrees. In addition, two teachers (2.7%) who participated in the survey had less than 1 year, ten teachers (13.5%) who had been in the 1~5 years, twenty-seven teachers (36.5%) who had been in the 6~15 years, thirty-one teachers (41.9%) who had been in the 16~25 years, and four teachers (5.4%) who had been teachers for more than 26 years (Table 2).

As of 2024, intelligent science labs have been installed at various elementary, middle, and high school levels nationwide, and the teachers who participated in the survey were currently intelligent science lab operators or users. However, the proportion of middle school teachers was relatively low. Also, sixty teachers (81.1%) Of the teachers who participated in the response said they had completed science education job training within the last three years, and fourteen teachers (18.9%) had not.

An analysis of the personal attributes of the teachers who participated in the survey regarding the use of the intelligent science lab revealed that among middle and high school teachers, those who specialized in physics and chemistry education were slightly more prevalent. Also, 58.1% of all the teachers surveyed held a bachelor's degree, 39.2% had a master's degree, 2.7% earned a doctoral degree, and 41.9% possessed a professional degree. They were grouped based on 15 years of teaching experience, and 83.8% of the participants had more than 5 years of field expertise. In addition, the completion rate of science teacher education was 81.1%, which was a high level; however, it may have been attributed to the education office's mandated or recommended science teacher training.

Table 2. The basic information of teachers

Major		Degree		Educational experience		Completion of science teacher training(within 3 years)	
Answer	N(%)	Answer	N(%)	Answer	N(%)	Answer	N(%)
Elementary education	27(36.5)	Bachelor	43(58.1)	less than 1 year	2(2.7)	Yes	60(81.1)
Physics education	16(21.6)	Master	29(39.2)	1~5 years	10(13.5)	No	14(18.9)
Chemistry education	14(18.9)	Doctor	2(2.7)	6~15 years	27(36.5)		
Biology education	10(13.5)			16~25 years	31(41.9)		
Earth science education	7(9.5)			26 years or more	4(5.4)		

Measurement

A questionnaire was created to determine teachers' perceptions of and use of the online platform intelligent science lab. The questionnaire questions were divided into essential information areas, intelligent science lab use areas, intelligent science lab platform areas, and simulation content areas through the R&D process at a regular meeting where four science education experts participated. Among the preliminary questions consisting of the first 20 questions, a questionnaire consisting of 10 basic information questions and 15 questions related to the intelligent science lab and content was produced by excluding five questions with low content validity or overlapping meanings with other items through a meeting by discussing until an agreement is reached four science education experts.

In the questionnaire in the area related to the intelligent science lab, the primary purpose of using the science lab and the frequency of use were asked to understand the relevance to the use of the platform of the intelligent science lab and the reason for choosing the response to the frequency of use was freely answered. Regarding the intelligent science lab platform, which is the primary survey area, the respondents were asked to respond to the purpose of using the platform, the frequency and reason for using the platform, the most used content on the platform, the primary purpose of content utilization, and the frequency and reason of using the content in class time. In addition, in the area related to simulation content related to scientific inquiry in the virtual world, it was configured to respond to questions about the frequency and utilization of class time, the ranking of the advantages and disadvantages of content, and the improvement plan.

The completed questionnaire was made to be answered online, and the survey was conducted after sending an official notice to participate in the survey through the Korea Foundation for Science and Creativity. Teachers were aware of the purpose and research content of the study, personal information-related matters, and compensation for answering the questionnaire before answering the questionnaire. They participated in the survey voluntarily, according to their willingness to participate. Among the collected responses, the responses of 80 teachers who responded to all the questions commonly were analyzed, the internal reliability of the questionnaire was analyzed, and the Cronbach α was found to be at an appropriate level of 0.86.

Analysis

The questionnaire for teachers comprised the essential information area, the intelligent science lab area, the intelligent science lab platform area, and the simulation content area. The questions for each domain were quantitatively analyzed to determine the number of respondents and their frequency. The reasons for responding to the frequency were collected as free responses. For the analysis of free-response responses, the content analysis method was used to construct an analysis framework for individual responses. The analytic framework for the qualitative data generated by the survey respondents was reviewed and discussed at a regular meeting of four science education experts until a consensus was reached. Afterward, the respondents' free responses were categorized according to the analysis framework, and the reasons for the responses were quantitatively analyzed by calculating the number of respondents for each category and converting them into quantitative data.

In addition, a regression analysis was conducted with nominal variables as dummy variables to determine whether respondents' variables such as gender, age, affiliated school level, major, educational experience, subject in charge, job training, and degree status collected in the essential information area affect the use of intelligent science lab and online platforms and contents. In addition, a regression analysis was performed in the area related to the intelligent science lab to check whether the purpose and frequency of use affect the use of the intelligent science lab platform and contents. In addition, since it was installed on the intelligent science lab platform and ranked the strengths and weaknesses of simulation contents used in the school field, the ranking average of each question was calculated. A chi-square test was conducted to confirm whether the responses to the rankings of strengths and weaknesses of the simulation contents were related to the basic information of teachers. In addition, Kendall's calculation of the ranking correlation coefficient for strengths and weaknesses confirmed whether teachers are consistent or independent in determining strengths and weaknesses. Through this, we derived what should be considered the primary considerations when developing simulation content from a teacher's point of view. In addition, regarding the improvement plan for simulation content, individual teachers' free-form responses were categorized and analyzed to identify additional considerations for developing simulation content.

Result & Discussion

The Result of Utilization on intelligent Science Lab & Platform

In order to investigate the extent to which the digital content mounted on the intelligent science lab platform is used in class activities, it is necessary to analyze the relationship with the utilization of the facility called the intelligent science laboratory. For this purpose, we analyzed the frequency of class use and the reasons for responding to the intelligent science lab and confirmed the results in Table 3. Regarding class time per week, the percentage of not using it at all ranked the highest at 37.84%. In the case of teachers who use the intelligent science lab for classes, it was confirmed that 1~3 hours per week was the most common result, with 29.73%, but the proportion of users who used more than 4 hours per week was 32.43% (4~6 classes: 12.16%, 7~9 classes: 5.41%, 10 classes more over: 14.86%). These results indicate that 62.16% of teachers use intelligent science labs in their science classes, and they are divided into those who use them frequently and those who do not. Therefore, there is a division between those who actively use the intelligent science lab facility in class and those who do not. Next, when we looked at the results of analyzing the questions about the reason for the frequency of class use by category, the group that did not use it at all was divided into the responses of 'Not in use science lab' (57.14%) and 'Lack of intelligent science lab' (39.29%). On the other hand, different response trends were found for different times of use in the group that used the intelligent science lab. As the number of hours spent per week in the intelligent science lab increased, it tended to be intended for science experimentation and inquiry lessons. Therefore, if scientific inquiry activities are frequently applied in the class, the utilization rate of intelligent science labs is high, and the utilization of related facilities is also high.

Table 3. The frequency and reasons of using the intelligent science lab for science class

Frequency of use per a week	N(%)	Reason of answer	N(%)
Not use	28(37.84)	Not in use science lab	16(57.14)
		Lack of intelligent science lab	11(39.29)
		Don't know how to use it	1(3.57)
1~3 classes	22(29.73)	Use of other science labs	1(4.55)
		Used for science lecture	7(31.82)
		Used for scientific inquiry lesson	4(18.18)
		Used for lesson on using digital devices	6(27.27)
		Used for club activities	4(18.18)
4~6 classes	9(12.16)	Used for science lecture	2(22.2)
		Used for scientific inquiry lesson	4(44.4)
		Used for lesson on using digital devices	2(22.2)
		Used for club activities	1(11.1)
7~9 classes	4(5.41)	Used for scientific inquiry lesson	2(50.0)
		Used for lesson on using digital devices	1(25.0)
		Used for club activities	1(25.0)
10 classes more over	11(14.86)	Used for science lecture	9(81.8)
		Used for scientific inquiry lesson	1(9.1)
		Used for lesson on using digital devices	1(9.1)

Since one of the research goals set in this study is to determine the degree of use of the content embedded in the intelligent science lab platform during science classes by the teaching staff of intelligent science laboratory model schools and leading schools, the results of the responses to the utilization questions of the intelligent science lab platform were analyzed (Table 4).

The proportion of teachers who did not use the intelligent science lab platform at all was 78.38%, and many teachers did not use the platform in their classes, and 17.57% of teachers used it for classes 1~3 times a week. In addition, 25.86% of teachers answered 'Not use,' and 12.07% answered 'Do not feel the need,' so it needs to be made aware of the platform's existence. However, 31.03% of teachers responded that they did not use it due to its low usability and inconvenience, and 20.69% said it was difficult to apply to their classes. Therefore, 51.72% of the reasons for not using it were low convenience and difficulty in utilization, and 37.93% were due to lack of publicity. Among the groups using the platform in classes, 30.77% answered that it can improve the learning effect, 23.08% said it is suitable for scientific inquiry, and 38.46% said it is difficult to use due to low convenience. Through this, it was found that low usability, convenience, and difficulty in applying classes are the main reasons for the low frequency of use of the intelligent science lab platform in classes. Therefore, to increase the use of intelligent science lab platforms in classes, they must be restructured to suit the teaching and learning process, improve usability, and be applied to classes.

Table 4. The frequency and reasons of using the intelligent science lab platform for science lesson

Frequency of use per a week	N(%)	Reason of answer	N(%)
Not use	58(78.38)	Do not know	15(25.86)
		Do not feel the need	7(12.07)
		Low usability and convenience	18(31.03)
		Difficulty applying lessons	12(20.69)
		Lack of useful content	6(10.34)
1~3 classes	13(17.57)	Low usability and convenience	3(23.08)
		Difficulty applying lessons	2(15.38)
		Suitable for scientific inquiry activities	3(23.08)
		Improving learning effectiveness	4(30.77)
		Suitable for using digital technology	1(7.69)
4~6 classes	2(2.70)	Suitable for scientific inquiry activities	1(50.00)
		Suitable for using digital technology	1(50.00)
7~9 classes	1(1.35)	Suitable for using digital technology	1(100.00)
10 classes more over	0(0.00)	-	-

The learning materials of the intelligent science lab platform are equipped with content developed to be used in various ways in science classes. They are configured to be searched and used according to school level and subject. In this regard, in order to derive the direction of improvement of simulation content that can be used in both science lecture-style classes and inquiry classes, it is necessary to analyze the utilization of the content mounted with the simulation content. The results of the analysis of the response results to the questionnaire are shown in Table 5.

Table 5. The frequency and reason of using the contents on intelligent science lab platform

Content on platform		Purpose of using contents by teachers	
Answer	N(%)	Answer	N(%)
Science Inquiry class	24(32.43)	Science lecture	2(8.33)
		Scientific inquiry activity	16(66.67)
		Scientific experiment activity	4(16.67)
		Science club activity	2(8.33)
Cooperation Inquiry	6(8.11)	Science lecture	1(16.67)
		Scientific inquiry activity	3(50.00)
		Scientific experiment activity	2(33.33)
		Science club activity	-
Realistic content	15(20.3)	Science lecture	1(6.67)
		Scientific inquiry activity	6(40.00)
		Scientific experiment activity	3(20.00)
		Science club activity	5(33.33)
Simulation	10(13.51)	Science lecture	3(30.00)
		Scientific inquiry activity	3(30.00)
		Scientific experiment activity	1(10.00)
		Science club activity	3(30.00)
Experiment safety	7(9.46)	Science lecture	1(14.29)
		Scientific inquiry activity	1(14.29)
		Scientific experiment activity	2(28.57)
		Science club activity	3(42.86)
Not used	12(16.22)	-	-

When asked whether they are using or planning to use the contents in the learning materials menu, 83.78% answered that they are currently using or planning to use them in their classes, while 16.22% answered that they will not use them. Teachers who responded that they would use the intelligent science lab platform content in their classes said they would use it for science lecture-style classes, scientific inquiry, scientific experiment activities, and science club activities. In particular, most of the contents installed in the intelligent science lab platform were intended to be used for 'Scientific inquiry activity.' However, in the case of simulation content, about 30% of the respondents said that they would use them in lecture-style classes, and 30% answered that they would use them in scientific inquiry activity. Therefore, science teachers answered that they would like to use the content in their classes according to the content categories presented by the intelligent science lab platform, and most of them will be used for scientific inquiry. In other words, there is a tendency to use 'science inquiry class materials' for research activities and development. Therefore, on-site teachers recognize the content presented on the intelligent science lab platform as suitable for scientific inquiry activities according to the introduction and explanation of each content, so they intend to use it in inquiry-oriented classes among science classes. Another reason for this tendency is that digital content to support teaching is seen as learning materials to support science lessons, and science teachers expect content that can support inquiry lessons, which require much effort.

The Utilization of Contents on intelligent Science Lab Platform

As a result of analyzing the responses of the teachers who participated in the survey, only 27.03% answered that they used the content embedded in the intelligent science lab platform in their classes, confirming that 72.97% of teachers do not use the content of the intelligent science lab in their teaching activities (Table 6). Additionally, 22.22% of teachers replied 'Not use' and indicated unfamiliarity with the content, while 14.81% said they did not see the need to use it. Therefore, it was found that 37.03% of teachers needed to be appropriately aware of the content of the intelligent science lab. In addition, 25.93% of the respondents said that they do not use it because of its low usability and convenience, and the rate of teachers who recognized that it is difficult to use in classes was 25.93%. Also, confirming that 51.86% of teachers do not use related content in their classes because it is inconvenient and difficult to use, and 11.11% of teachers said it was due to a lack of content that was useful enough to be used in their lessons.

On the other hand, most of the teachers who used the contents of the intelligent science lab in their classes applied about 1~3 times per week, and a small number of teachers used them for more than 4 hours per week because they were suitable for using digital technology. In addition, 22.22% of teachers who use it for more than one class per week said that it is because it is suitable for using digital technology. It is because these responses are linked to sensors or use external data among the contents of the intelligent science lab platform, and they are also running on mobile devices. On the other hand, 44.44% of the teachers answered that it effectively improves learning efficiency, and 22.22% answered that it is suitable for scientific inquiry activities. Therefore, it means that many teachers do not use the content of the intelligent science lab platform in their classes, but some teachers actively use it in their classes and use it effectively. This difference is because the quality of the content is different, and the teacher decides whether to use it in the actual class by evaluating the relevance and suitability of the teacher's lesson. In particular, content developers need to pay attention to this part because teachers' responses that they do not use content because of its low utilization and difficulty in applying it to science classes are user responses that use digital content in class. Therefore, if there is no intuitive and efficient content, it can be considered that the usability is low because the time spent on class management, such as individual explanations to students, may be required more than the student activities or actual learning time when teachers use it in class.

Table 6. The frequency and reason of using the contents for science class

Content on Platform Frequency of use per a week	N(%)	Reason of answer	N(%)
Not use	54(72.97)	Do not know	12(22.22)
		Do not feel the need	8(14.81)
		Low usability and convenience	14(25.93)
		Difficulty applying lessons	14(25.93)
		Lack of useful content	6(11.11)
1~3 classes	18(24.32)	Low usability and convenience	1(5.56)
		Lack of useful content	1(5.56)
		Improving learning effectiveness	8(44.44)
		Suitable for scientific inquiry activities	4(22.22)
		Suitable for using digital technology	4(22.22)
4~6 classes	1(1.35)	Suitable for using digital technology	1(100.00)
7~9 classes	0(0.00)	-	-
10 classes more over	1(1.35)	Suitable for using digital technology	1(100.00)

As a result of analyzing the responses on the frequency of using the simulation content of the ON platform of the intelligent science lab in class, 86.49% answered that they do not use it in class, and 12.16% used it within 1~3 hours per week. The other 1.35% answered 7~9 hours. In addition, as a result of analyzing teachers' responses to the question of which subjects would be most likely to use simulation content, 31.25% of them used it in elementary science subjects, 11.25% in middle school science, 9.46% in high school integrated science and science inquiry experiments, 21.62% in high school general elective subjects, and 14.86% said they did not use it at all. Therefore, compared to elementary and middle schools, the utilization rate of simulation content in high school subjects was 40.54%, which confirmed that it could be used the most. However, middle schools showed a relatively low utilization level because the middle school teachers of participants are small (Table 7).

Table 7. The main subjects utilizing the simulation content of the intelligent science lab platform

Curriculum		Subjects	N	%
Elementary school		Science	24	32.43
Middle school		Science	9	12.16
High school	General elective curriculum	Integrated science	7	9.46
		Science Inquiry experiment	7	9.46
	Career elective curriculum	Physics	5	6.76
		Chemistry	2	2.70
		Life science	6	8.11
		Earth science	3	4.05
Not use			11	14.86

The Essential Factor of Simulation Content for Science Inquiry Class

In order to investigate the essential element of simulation content for science class, researchers asked for the advantages and disadvantages of simulation content mounted on the intelligent science lab platform. The teacher answered that the general characteristics of the simulation content were ranked according to survey items about the advantages and disadvantages of simulation content. The result of the analysis for the advantage ranking from the teachers' responses was that implementing a virtual world for scientific inq`uiry was the most mentioned feature and the first-ranked advantage of the simulation content. The second priority was to save the time required for inquiry activities, the third was to save time and effort to prepare for activities, the fourth was to stimulate learners' interest, and the fifth was to provide a realistic virtual experience. Therefore, it was found that teachers value the implementation of scientific inquiry activities and the effort required to prepare for inquiry activities rather than the sense of reality or learner interest in simulation content (Table 8).

Table 8. The ranked result of advantages for simulation content in intelligent science lab platform

Ranking of advantages	1st Priority N (%)	2nd Priority N (%)	3rd Priority N (%)	4th Priority N (%)	5th Priority N (%)
Implementation of virtual worlds for science inquiry activity	29(39.19)	11(14.86)	18(24.32)	6(8.11)	13(17.57)
Motivation to learn	21(28.38)	13(17.57)	8(10.81)	28(37.84)	3(4.05)
Providing realistic virtual experiences	10(13.51)	9(12.16)	11(14.86)	8(10.81)	30(40.54)
Saving time for inquiry activity	8(10.81)	28(37.84)	11(14.86)	17(22.97)	12(16.22)
Reducing time and effort for activity preparation	6(8.11)	13(17.57)	26(35.14)	15(20.27)	16(21.62)

These results suggest that teachers may use it less frequently when there is a mismatch between teachers' expectations of the functionality of digital content as teaching and learning materials and the characteristics of actual content. Therefore, if we consider the aspect of teacher utilization in the development of simulation content, it is necessary to consider the appropriateness of implementing scientific inquiry activities and configuring the user interface to increase usability.

According to the analysis of the disadvantages of simulation contents, the first ranked disadvantage was the insufficient implementation of scientific inquiry, the second was an increase in the time required for activities, the third was an increase in preparation time and effort, the fourth was stimulating learners' interest, and the fifth was providing a realistic virtual experience (Table 9). These results are consistent with teachers' perception of digitized simulation content, with responses from the same perspective as advantage rankings. Therefore, it is important to consider whether these results are general or due to the personal vari`ables of the teachers who participated in the responses.

Table 9. The ranked result of disadvantages for simulation content in intelligent science lab platform

Ranking of disadvantages	1st Priority N (%)	2nd Priority N (%)	3rd Priority N (%)	4th Priority N (%)	5th Priority N (%)
Insufficient implementation of science inquiry activities	27(34.49)	15(20.27)	12(16.22)	11(14.86)	13(17.57)
Lack of realistic virtual experiences	16(21.62)	9(12.16)	8(10.81)	6(8.11)	29(39.19)
Increased time and effort for preparation	13(17.57)	14(18.92)	27(36.49)	11(14.86)	7(9.46)
Extended time required for inquiry activities	12(16.22)	25(33.78)	14(18.92)	18(24.32)	7(9.46)
Limited ability to motivation to learn	6(8.11)	11(14.86)	13(17.57)	28(37.84)	18(24.32)

A chi-square test was conducted to determine whether the responses to the rankings of advantages and disadvantages of simulated content were related to the basic information of teachers, and no difference was found according to teacher factors in most of the responses, except for some. It was found that there was a significant difference in responses to the second-ranked advantage, χ^2=37.255, p= 0.041, depending on the teacher's career. Regarding responses to the second-ranked advantage, teachers with 6 to 10 years of educational experience realized the virtual world of scientific inquiry activities and the induction of learner interest. In comparison, teachers with 11 to 15 years of educational experience presented practical virtual experiences, while the rest suggested saving time in inquiry activities as the second-ranked advantage. On the other hand, teachers with 11 to 15 years of educational experience and teachers with 20 to 25 years of educational experience suggested inducing learner interest and saving time in inquiry activities as the first-ranked advantage, while the rest of the teachers presented the virtual world of inquiry activities as the first-ranked advantage. It means that the degree to which teachers perceive the advantages of simulation content differs according to their careers, suggesting that there may be differences in perceptions of scientific inquiry activities and the use of digital content depending on the teacher's life cycle.

Next, χ^2=11.532, p=0.021 showed a significant difference in response to the first-priority disadvantage according to gender. Men presented poor implementation of scientific inquiry activities as the first-priority disadvantage. In contrast, women presented the first-priority disadvantage at a similar rate, such as increased time required for inquiry activities, insufficient provision of realistic virtual experiences, and insufficient implementation of scientific inquiry activities. In other words, women viewed the shortcomings of simulation content in various ways depending on the individual, while male teachers recognized the lack of implementation of scientific inquiry activities as the main disadvantage. However, for the priority advantage, both women and men recognized the realization of the virtual world of scientific inquiry activities as a major advantage. Therefore, teachers recognize the virtual world of inquiry activities as important. However, it can be seen that the existing contents that were implemented recognize that the realization of scientific inquiry activities is insufficient.

Regarding responses according to the school level, statistically significant differences were identified as χ^2=18.711, p=0.016 in the fourth-priority disadvantage. In the case of high school teachers, insufficient inducement of learner interest was suggested as the main fourth-priority disadvantage. In contrast, middle school teachers suggested increasing the time required for inquiry activities as the main fourth-priority disadvantage, and elementary school teachers cited the lack of implementation of science inquiry activities. It was presented as the fourth-priority disadvantage, meaning it is not recognized as a significant disadvantage. Elementary, middle, and high school teachers responded that implementing inquiry activities was insufficient for the first-priority disadvantage. They suggested that the priority advantage was implementing science inquiry activities. In other words, there was a difference between expected and observed values in ranking factors other than implementing science inquiry activities, which are recognized as significant strengths and weaknesses. Therefore, since the degree to which simulation content is perceived as a disadvantage may differ depending on the school level, it is necessary to consider the suitability of implementation of science inquiry activities, the economics and effectiveness of inquiry activities, the composition considering user convenience, and the induction of realistic virtual experiences and interests at an appropriate level.

Next, the results of calculating Kendall's ranking correlation coefficient to confirm whether there is a relationship or independence between the rankings in determining the strengths and weaknesses of teachers are shown in Table 10. Particularly significant positive correlations were the first and fifth advantages (τ = 0.300, p<0.01), the second and fourth disadvantages (τ = 0.199, p<0.05), and the third and fourth disadvantages (τ = 0.241, p<0.05). On the other hand, significant negative correlations were the first and fourth disadvantages (τ =-0.352, p<0.01), the second and fifth advantages (τ =-0.287, p<0.01), the third and fifth disadvantages (τ =-0.233, p<0.05), the first and second disadvantages (τ =-0.243, p<0.01), the first and fourth disadvantages (τ =-0.253, p<0.01), the third disadvantages and the fourth disadvantages (τ =-0.213, p<0.05).

Table 10. The result of rank correlation analysis on the advantages and disadvantages of simulation content

	Advantage 1st	Advantage 2nd	Advantage 3rd	Advantage 4th	Advantage 5th	Disadvantage 1st	Disadvantage 2nd	Disadvantage 3rd	Disadvantage 4th	Disadvantage 5th
Advantage 1st	1.000									
Advantage 2nd	-0.091	1.000								
Advantage 3rd	-0.393**	-0.100	1.000							
Advantage 4th	-0.118	-0.110	-0.116	1.000						
Advantage 5th	-0.056	-0.287**	-0.179	0.005	1.000					
Disadvantage 1st	0.144	0.022	-0.108	-0.083	0.171	1.000				
Disadvantage 2nd	-0.027	0.017	0.184	-0.008	-0.034	-0.243*	1.000			
Disadvantage 3rd	0.071	-0.026	0.074	-0.007	-0.021	0.015	-0.188*	1.000		
Disadvantage 4th	-0.352**	0.199*	0.241*	0.061	-0.056	-0.253**	-0.048	-0.213**	1.000	
Disadvantage 5th	0.300**	-0.015	-0.233*	0.106	0.062	-0.106	-0.148	-0.072	-0.179	1.000

*: p<0.05, **: p<0.01

Therefore, teachers recognize that realizing the virtual world of scientific inquiry activities, which is the first advantage, can offset the inadequate part of the learning motivation, which is the fifth disadvantage. In addition, if learning motivation is well provided through experiences similar to reality, it is perceived as an advantage even if it takes a long time to explore. However, a longer time to perform the content could conflict with effectiveness and efficiency. It means that teachers can recognize that the long time spent performing content is unsuitable for their science inquiry class.

Also, as a result of analyzing teachers' responses to open-ended questions about how to improve simulation content mounted on the intelligent science lab platform (Table 11), 24.19% of 64 teachers who responded suggested that the development of linked content was necessary, and 20.97% of teachers said that the ease of use needed to be improved. In addition, 17.74% suggested that it is necessary to diversify the topics and contents of content, and 14.52% suggested that it is necessary to expand the training and promotion of its use. The remaining 11.29% suggested that teachers need to improve the quality of content, and 4.84% answered that simulation contents need to be integrated with external hardware and software. Therefore, in order to consider the on-site utilization of simulation content mounted on the intelligent science lab platform, it is necessary to have content linked to textbooks; it must be convenient to use and content with a quality level that teachers can use in science classes, with a variety of topics and contents. In addition, it will be necessary to conduct training and publicity for teachers to utilize the developed content.

Table 11. The improvement strategies for simulation content of intelligent science lab platform

Improvement strategies	N	%
Development of content linked to textbooks	15	24.19
Integration with external hardware and software	3	4.84
Diversification of content themes and topics	11	17.74
Enhancement of realism in content	5	6.45
Improvement of content quality	8	11.29
Increased usability and convenience	13	20.97
Expansion of training and promotion activities	9	14.52

The reasons for not using the digital content of intelligent science lab platforms are unsuitable for science activities in class, inconvenience of operating the contents, low level of motivation, and so on. In order to solve this problem, it is essential to understand the needs of teachers during the content development planning and development stage and to organize them into practical teaching and learning as meaningful content.

According to the result of this study, the first essential factor of simulation contents is the realistic implementation of scientific inquiry. Therefore, it is necessary to provide a degree of freedom to experience inquiry activities freely, the essence of science learning, and to secure a teaching and learning composition suitable for the science inquiry process first. Next, the balance of effectiveness and efficiency for scientific activity using simulation content is essential in digital content development. In other words, digital content should provide a suitable process for inquiry activities and save the time teachers spend preparing and performing student activities. Finally, digital simulation should support the science learning process, considering learning motivation, convenient user interface, and familiar operational functions such as features similar to those experienced in everyday life.

Discussion

The learning activity using digital content in class can provide more benefits, such as learning achievement and student engagement, than traditional activities (Zheng et al., 2024). However, it does not mean traditional teaching and learning strategies are unuseful in-class activities using digital content to assist teachers and students. Instead, science inquiry activities should consist of an empirical process of generating knowledge and acquiring concepts through scientific problem-solving (Fauth et al., 2019; Yildiz & Yildiz, 2021). In the context of a digital-based learning environment, scientific thinking, such as hypothetical deductive thinking, is the most important factor for students to learn and perform scientific inquiry effectively. Because the scientific thinking process allows students to modify concepts, generate predictions, formulate hypotheses, and analyze data.(Kalinowski & Pelakh, 2024). Therefore, even in digital simulation-based virtual inquiry activities, it is the first essential factor to organize the learning process so that students can learn scientific methods and change concepts by providing experiences of knowledge generation and acceptance through scientific thinking.

Next, in the results of this study, the main characteristic that science teachers expect as the advantage of simulation content was the appropriate implementation of scientific inquiry activities. In this respect, it means that science inquiry activities are established as an important learning method in the perception of teachers interacting with students in the science education field, proving that scientific inquiry activities are still recognized as complex objects to implement. In addition, teachers expected to reduce the time required to prepare for and perform learning by utilizing simulation content, just like the view that it is important to consider the economics and efficiency of learning when using simulation data that implement activities in a virtual world (Holmes et al., 2019). These results are also related to replacing learning experiences in the virtual world, such as experiments that take a long time or do not reveal results when implemented for classes, which could be more efficient than activity in the actual class (Tao et al., 2024). Therefore, it is essential to provide a function such as a diagnosis test, a detailed explanation of the inquiry process, and a demonstration of experimental tool operation to support teachers in the classroom to relieve the burden and difficulties of science inquiry activities.

Providing realistic experiences in learning activity requires more costs to be submitted, but can further increase the effectiveness of learning in terms of knowledge and conceptual acquisition and satisfaction (McBane et al., 2023). Also, digital simulation can provide the freedom controlling of conditions for various environments and can be operated to verify hypotheses through user manipulation (Heuermann et al., 2023; Verkuyl et al., 2024). Therefore, due to these characteristics, learning activities using digital simulations can be more effective in science education. On the other hand, the complexity of the content or the extension of the time required for the use of simulation learning materials in class can act as a learning obstacle (Jimenez, et al., 2023; Luo et al., 2021)

. In a similar context, teachers who participated in this study answered that the essential factor of simulation content is the science learning process considered for learning motivation and usage convenience of content. It means that the various and free operation of scientific variables of simulation content for scientific inquiry is an important factor. However, much complexity and inconvenience of operation can decline the positive effect of simulation content on learning success. Although it is expected that the realistic implementation of a virtual world of scientific inquiry activities, including various variables operations, will contribute to efficiently reducing inquiry time, it has been recognized that learning motivation may not be significantly improved in complex and unfamiliar operations (Chau et al., 2022; Liaw et al., 2022). Therefore, in order to develop digital simulation content that supports science learning, it is essential to consider learning motivation, convenient user interface, and ease of operational function.

Conclusions and Educational Implications

The utilization status of the Intelligent Science Lab platform and the extent to which digital content is used in educational settings were examined. The following conclusions are drawn from analyzing factors to consider when developing simulation content.

First, improving the practical utilization of the intelligent science lab platform is necessary. The study found that 73% of responding teachers do not use the platform for their classes, and the most common reasons cited were low usability and difficulty applying to classes. It means that the utilization of the platform and content of the intelligent science lab is currently limited. Therefore, the platform's design needs to reflect the classroom needs of teachers and students sufficiently, and the ease of use and content organization needs improvement.

Second, it is necessary to strengthen the suitability of implementing the inquiry activities and the sense of reality to maximize the educational effect of simulation contents. Teachers cited the implementation of virtual worlds and saving time on activities as the main advantages, but the lack of implementation of inquiry activities and lack of a sense of reality as the main disadvantages. This study suggests that content needs to be improved to provide simulation experiences and maximize learning effectiveness. Therefore, it needs to recognize that simulation content is a valuable tool in learning scientific inquiry but has limitations. Also, simulation contents should be made to balance the implementation of science inquiry activity and efficiency for the assistance of the teacher's class.

Third, the key elements of simulation content improvement should be considered in the user context for science class. According to the findings, teachers ranked linkage to textbooks and ease of use for learners as the most important factors in content development. In addition, diversification of topics and content and improvement of the quality of content were also important requirements. This result shows that for simulation content to be effectively used in the school, it is essential to connect with the lesson closely as high-quality content. Therefore, simulation content should be developed to satisfy the needs of teachers and learners simultaneously, thereby increasing its practical utility in the school field. Consequently, developing effective simulation content requires curriculum relevance, ease of use, subject diversity, and improved content quality. These will allow teachers and students to feel both satisfaction and efficiency in their scientific inquiry.

This study confirmed the current status of the use of intelligent science labs and platforms, and the following educational implications can be presented by suggesting the core elements of digital content needed in school sites. First, the content of the intelligent science lab platform can be used as a universal tool to support scientific inquiry in the school field. For example, in situations where real-world experiments are complex or risky, virtual simulations can provide safety and efficiency as an alternative to experiments. To this end, it is necessary to develop content linked to textbooks and design learning materials suitable for the curriculum at each school level. Second, it is necessary to promote systematic training programs and platforms to strengthen teachers' competencies. Practical training and sharing of use cases are essential for teachers to be aware of the utility of digital content and actively use it. Significantly, we must make digital content more accessible by providing customized training tailored to teachers' classroom environments. Third, follow-up studies should validate the specific effects of simulation content on learner-centered scientific thinking, problem-solving skills, and motivation to learn. It will provide practical proof of the educational effectiveness of the content and provide an important basis for future content development and policy design.

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