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RESEARCH ARTICLE

The Effects of Using Smart Devices in Student-Participatory Science Classes : Focusing on Core Competencies, Positive Science Experiences, and Class Satisfaction

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ABSTRACT

Since the spread of COVID-19, schools have been equipped with environments that can use smart devices, and the curriculum emphasizes student-centered classes using digital devices. In this context, this study conducted a flipped classroom style of student-participatory science class using smart devices for 30 sessions targeting 60 male students in three middle school classes. A survey was conducted and analyzed to explore the effects of such science classes on the cultivation of core competencies in science emphasized in the national curriculum, improvement of positive experience indicators in science, and satisfaction with science classes. The results of the study showed that student-participatory science classes using smart devices were effective in cultivating core competencies such as scientific problem-solving ability, scientific communication ability, and scientific inquiry ability. It also had a significant effect on improving positive experience indicators in science, including students' attitudes towards science and motivation for science learning. Students not only found the class interesting by using various programs with smart devices, but also understood the learning well and had high satisfaction with the science class. Therefore, it suggests that using smart devices in science classes can be a useful teaching and learning strategy. On the other hand, it requires the teacher's guidance and management to use smart devices correctly and effectively during class. In the future, there is a need to explore ways to efficiently use various and useful learning apps and AI programs that can be utilized with smart devices.

Keywords: Smart devices, student-participatory class, science class, core competency, positive experience in science, class satisfaction

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Introduction

In the modern era of the Fourth Industrial Revolution, rapid advancements are being made in science, engineering, and technology, including artificial intelligence (AI), the IoT, blockchain, autonomous transportation, 3D printing, robotics, and gene editing (Choi, 2016). In line with this trend, the Ministry of Education has implemented a smart education initiative centered around digital textbooks, software education, and ICT projects (MOEST, 2011). Smart education reflects integrated technological advancements that support activities both inside and outside the classroom, leading to widespread distribution of smart devices in schools and an emphasis on student-centered learning using digital devices. Smart devices used in educational settings include smartphones, tablets, and laptops that can connect to the internet, access various information, and utilize software and applications.

Prior to the spread of COVID-19 in 2020, the educational informatization infrastructure in elementary, middle, and high schools was insufficient, with less than one smart device per student group (KERIS, 2020). Challenges such as a lack of educational applications and programs, inadequate wireless internet networks, and information security issues made it difficult to effectively use smart devices in classroom instruction. Consequently, the Ministry of Education provided policy support in various forms, such as digital textbook pilot schools, software education pilot schools, future education pilot schools, and online content utilization pilot schools. This led to an increase in the distribution of various types of smart devices, including tablet PCs, hybrid laptops (Chromebooks, Whalebooks, Windows books), and standard laptops. However, the active use of such smart devices in all school classes nationwide remained limited. The COVID-19 pandemic, which began in 2020, led to frequent delays in school openings and transitions to online remote learning, accelerating the distribution of smart devices in most schools and increasing the use of smart devices in classes. The pandemic has shifted the paradigm of teaching and learning methods in schools (Whalley et al., 2021).

Meanwhile, since the 2015 revised curriculum (MOE, 2015), the direction of science education has emphasized student participation using the internet and digital devices. The 2022 revised science curriculum (MOE, 2022) further encourages the appropriate use of the latest ICT and devices, such as VR/AR materials, software, computers, and smart devices, in experiments and inquiries. This direction in science education can contribute to fostering students' core scientific competencies and enhancing affective domain achievements in science (Kim et al., 2012; Lee et al., 2013). Therefore, the need for smart device-based education in schools has increased, and its potential to facilitate meaningful learning experiences has been reported (Kim & Lim, 2017; Leem & Kim, 2016; Karim et al., 2021; Sakibayev, 2021; Williams et al., 2017).

The recent policy initiative, the Green Smart Future School Project (MOE, 2021), is normalizing the use of smart devices in science class activities. Research on the effects of smart device use in science education has been conducted in various contexts, including remote learning (Byun, 2021), studies targeting elementary students (Jin & Shin, 2016), and research on the effects of individualized learning (Yun et al., 2015). Smart devices and multimedia resources can help learners more easily understand scientific concepts related to the micro-world (Avraamidou, 2008; Dimitriadou & Lanitis, 2023; Williams & Pence, 2011) and facilitate communication during inquiry-based and various student-centered activities (Chang & Joung, 2017; Nam et al., 2017). They can also increase the efficiency of diagnostic and formative assessments and student engagement (Kang et al., 2014). Additionally, the use of smart devices in seven science lessons has been shown to aid scientific understanding and be useful for individualized learning (Yun et al., 2015). Song & Jeong (2023) developed and applied inquiry-based teaching and learning materials for the high school biology-I curriculum using smart devices across five topics, demonstrating that students became more interested and actively participated in science classes.

Despite this, systematic case studies analyzing the impact of smart device use on core competency development and positive science experiences emphasized in the national science curriculum are rare. Moreover, most existing research focuses on the short-term effects of smart device use over a few lessons. Therefore, case studies exploring the long-term effects of science education using smart devices over a semester are needed.

The widespread use of PCs and smartphones has enabled the application of 'flipped learning,' which utilizes various technologies such as video lectures, online materials, applications, and mobile devices (Kim, 2015; Kim, 2019; Leem & Kim, 2016). In flipped learning, students familiarize themselves with the content through video lectures, online materials, and textbooks before class, and then participate in inquiry, research, discussion, and concept learning activities in the classroom (Min & Kim, 2021; Sams & Bergmann, 2013; Zheng et al., 2020). Thus, flipped learning can be considered one of the appropriate instructional models for effectively integrating smart devices into science education.

This study applies a flipped learning model of student participation in science classes using smart devices over an extended period. It aims to explore the effects on students' core competencies, positive experiences in science, and class satisfaction as emphasized in the national curriculum. The specific research questions are as follows:

1. Does the use of smart devices in science classes effectively foster students' core scientific competencies?
2. Does the use of smart devices in science classes enhance students' positive experiences in science?
3. How do students perceive science classes that utilize smart devices?

Methods

Participants

This study was conducted with 60 male students in the third grade at C-Middle School located in Gyeongsangnam-do. The participants were divided into three classes, each consisting of 20 students. The lessons for each class were carried out in the science laboratory by a single science teacher, based on the same teaching and learning plan and in the same manner.

Prior to the start of the lessons in this study, the students had only experienced traditional teacher-led, lecture-based instruction, and this was their first time participating in lessons utilizing smart devices. C-Middle School had been selected as a leading school for the use of online content and had set up 30 Chromebooks (laptops) and a wireless internet environment in the science laboratory during the vacation period just before the start of the research. Additionally, Google Workspace, a cloud-based collaboration service, was introduced to create an environment suitable for operating science classes using smart devices.

The teacher in charge of the lessons is a male middle school science teacher with 11 years of experience. He has participated as an instructor in the smart education support group and digital textbook utilization group promoted by the

Gyeongsangnam-do Office of Education and is active as a Google Certified Trainer. Therefore, this teacher is evaluated as having excellent ability to effectively utilize smart devices to operate science classes and guide students.

Procedure

Class Procedure

The teaching and learning activities in this study were structured as shown in Fig. 1, based on the flipped learning model proposed in previous studies (Kim, 2015; Kim et al., 2019). The classes were operated based on the student participation-oriented science class approach (Min & Kim, 2021; Min, 2022), allowing students to engage in various student-centered activities such as research, experiments, discussions, and presentations. Teachers and students utilized educational platforms and apps, digital science textbooks, video lectures, online materials, VR/AR, etc., in their teaching and learning activities.

Stage	Teaching-Learning Activities	Utilizing Smart Device
Pre-learning	-Self-study Using Videos and Learning Sheets at Home or School Before Class	-Educational Platform (Classroom)
Check of Pre-learning	-Confirmation of Completion of Pre-learning -Q&A, Supplementary Explanation	-Digital Textbook -Classroom Materials
Class Guide	-Group Formation -Guidance on the Procedure and Method of Learning Activities	-Classroom Materials -Video Guide Materials
Teaching-Learning Activity	-Teacher: Circulating Guidance and Feedback, Assistance with the Operation of Smart Devices, -Student: Submission of Learning Activity Results to Classroom, Presentation	-Digital Textbook -Classroom Materials -Spreadsheet (Excel) -Google Online Documents -Immersive Content (VR/AR) -Video Learning Materials
Summary and Evaluation	-Summarization of Learning Content -Formative Evaluation	-Quiz App. (Quiz N) -Google Forms

Fig. 1. Stages of flipped learning and utilizing smart devices

Teaching-Learning Programs

In this study, student-participatory science classes using smart devices were conducted four times a week, with no classes held on public holidays and school event days. Before the application of the class program, two class hours were spent educating on how to use educational apps, educational platforms, and digital textbooks with smart devices.

The overall class program was composed of a total of 30 sessions, including 12 sessions for the 'Atmosphere and Weather' unit, 10 sessions for the 'Motion and Energy' unit, and 8 sessions for the 'Stimulus and Response' unit of the third-grade science curriculum in middle school. This signifies that student-participatory science classes using smart devices were applied over a semester.

Each session's class program was designed to provide convenience in learning activities and help understand the learning content by allowing students to utilize various educational apps and materials through smart devices. To aid in understanding the teaching and learning program using smart devices, a basic example is presented in Fig. 2.

Stage	Teaching-Learning Activities
Pre-learning	• Providing the basic content of 'e-Learning Center' (Middle School-3rd grade) science videos in the form of URL in 'Google Classroom' • Learning through questions and pre-learning worksheets (insert brackets) in 'Google Classroom'
↓	↓
Check of Pre-learning	• Confirming/Evaluating pre-learning content with 'Digital Textbook' and worksheets • Query/Response/Supplementary explanation related to misconceptions in pre-learning content
↓	↓
Class Guide	• Guiding immersive content and worksheets (Google Documents) uploaded in 'Classroom' • Guiding precautions when writing worksheets
↓	↓
Teaching-Learning Activity	• Learning three-dimensional/video materials such as VR/AR and Videos • Conducting experiments or exploratory activities depending on the class topic • Teachers circulate, guide, and assist with device operation • Learning worksheets (Google Documents) with 'Chromebook (Laptop)' -(Example) "How does the temperature change with altitude in the atmosphere?" 1) Represent the temperature distribution according to height in a graph 2) Answer in the worksheet based on the activities • Submitting the written worksheet to 'Classroom' -Connecting the submitted worksheet to a beam projector for presentation/ feedback • Presenting 'Advanced Tasks' to students who finish activities quickly -(Example) If there is no ozone layer in the stratosphere, how would the temperature distribution according to height appear?
↓	↓
Summary and Evaluation	• Summarizing the class content based on the worksheet content • Conducting formative evaluation using 'Google Forms' or 'Quiz N' App."

Fig. 2. Example of student-participatory class process in the form of flipped learning using smart devices

Questionnaire and Data Analysis

Questionnaire

In this study, a survey was conducted to measure students' core scientific competencies, positive experiences in science, and class satisfaction. To explore whether there were changes in the level of students' core scientific competencies through science classes using smart devices, a survey tool developed by Ha et al. (2018) was used.

The survey tool for the level of core scientific competencies consists of a total of 25 items, including 5 items for scientific thinking, 5 items for scientific inquiry ability, 5 items for scientific problem-solving ability, 5 items for scientific communication ability, and 5 items for scientific participation and lifelong learning ability. For each item, self-perception was rated on a 5-point Likert scale, with 1 point for Strongly Disagree, 2 points for Disagree, 3 points for Neutral, 4 points for Agree, and 5 points for Strongly Agree. The pre-reliability of the survey tool for core scientific competencies was .966, and the post-reliability was .982.

To explore whether there were changes in students' positive experiences in science through science classes using smart devices, a survey tool for positive experiences in science developed by Shin et al. (2017) was used. This consists of 5 sub-areas and a total of 35 items. The sub-areas are composed of 6 items for science learning emotions, 6 items for self-concept related to science, 10 items for science learning motivation, 5 items for career aspirations related to science, and 8 items for attitudes related to science. For each item, self-perception was rated on a 4-point Likert scale. The pre-reliability of the survey tool for positive experiences in science was .946, and the post-reliability was .949.

To find out students' satisfaction with science classes using smart devices, a survey tool (Table 1) for post-class satisfaction for science classes was improved based on the questionnaire created by Kim (2020). Except for 2 descriptive items, the remaining 6 items were rated on a 5-point Likert scale for self-perception. The reliability of the items in the class satisfaction survey tool was .915.

Table 1. Survey Items for Satisfaction with Student-Participatory Science Classes Using Smart Devices

Type	Satisfaction Survey Items
5 -point Scale	1. How satisfied are you with the student-participatory science class using smart devices?
	2. Do you feel that your science skills have improved after the student-participatory science class using smart devices?
	3. Was the student-participatory science class using smart devices a customized learning that matched my learning speed or science ability?
	4. Was the student-participatory science class using smart devices more interesting than other subjects?
	5. Do you feel that your digital device usage skills have improved after the student-participatory science class using smart devices?
	6. Were you able to communicate with other friends in the student-participatory science class using smart devices? Descriptive
Essay Type	7. Describe the advantages of the student-participatory science class using smart devices.
	8. Describe the disadvantages of the student-participatory science class using smart devices.

Data Analysis

The results of the quantitative survey data were analyzed using the SPSS program (v.27). Firstly, the reliability (Cronbach's α) of the survey instruments for science core competencies, positive science experience indicators, and science class satisfaction was analyzed, and normality tests (Shapiro-Wilk test) were conducted for the survey items on positive science experience indicators and science core competencies.

Secondly, to evaluate whether there was a statistically significant difference in the scores of positive science experience indicators and science core competencies before and after the student-centered classes, paired-sample t-tests were conducted. However, for items that did not meet normality, non-parametric tests, namely the Wilcoxon signed-rank test, were performed.

Thirdly, descriptive statistics were calculated for the responses to six survey items related to the satisfaction of student-centered science classes using smart devices. Additionally, the responses to two open-ended items were categorized into advantages and disadvantages of teaching and learning activities when utilizing smart devices and were organized by type.

Results

Effect on Science Core Competencies

The analysis of the effect of student-centered science classes using smart devices on science core competencies is presented in Table 2. A paired sample t-test was conducted to compare pre- and post-scores, and a non-parametric test was performed for scientific inquiry abilities due to a normality test statistic of 0.122 (p=.042).

The analysis revealed significant increases in post-scores compared to pre-scores in all areas: scientific thinking (t=3.556, p=.001), scientific inquiry (Z=3.866, p=.000), scientific problem-solving (t=4.873, p=.000), scientific communication (t=4.613, p=.000), and scientific participation (t=3.924, p=.000), as well as the overall area of science core competencies (t=4.446, p=.000).

Notably, scientific problem-solving and communication skills showed substantial improvement, followed by scientific participation, inquiry, and thinking, in that order. This suggests that science classes utilizing smart devices are effective in enhancing students' science core competencies.

Table 2. Testing the changes in science core competencies

Core Competency Area	Pre (I)		Post (J)		MD (J-I)	t	p
	M	SD	M	SD			
Scientific Thinking Ability	3.16	1.77	3.75	1.91	0.59	3 .556	. 001
Scientific Inquiry Ability	3.05	1.80	3.76	1.02	0.71	3 .866 *	. 000
Scientific Problem-Solving Ability	3.10	1.82	3.88	1.91	0.78	4 .873	. 000
Scientific Communication Ability	3.02	1.75	3.76	1.97	0.74	4 .613	. 000
Scientific Participation Ability	3.10	1.82	3.78	1.94	0.68	3 .924	. 000
Overall	3.09	1.73	3.79	1.91	0.70	4 .446	. 000

* : Test Statistic Z of Wilcoxon Signed-Rank Test (Negative Rank Sum: -211.50, Positive Rank Sum: 964.50)

Effect on Positive Science Experiences Indicators

The results of the examination of the effect of student-centered science classes using smart devices on positive science experience indicators are shown in Table 3. Paired sample t-tests were conducted for areas such as science-related self-concept, science learning motivation, and career aspirations in science. Non-parametric tests were carried out for science learning emotions, with a statistic of 0.944 (p=.013), and attitudes towards science, with a statistic of 0.124 (p=.034), due to the normality test results.

The analysis indicated significant changes in pre- and post-survey values in the order of career aspirations in science, attitudes towards science, science learning emotions, science learning motivation, and science-related self-concept, with statistically significant differences in each indicator area. A significant difference was also observed in the overall area of positive science experience indicators (t=-5.844, p=.000). Therefore, it can be concluded that science classes using smart devices effectively increase students' positive experiences in science.

Table 3. Testing the changes in positive science experience indicators

Area	Pre (I)		Post (J)		MD (J -I)	t	p
	M	SD	M	SD			
Science Learning Emotion	2.94	0 .53	3 .46	0 .51	0 .52	4.368*	. 000
Science-related Self-concept	2.52	0 .61	2 .97	0 .79	0 .45	3.935	. 000
Science Learning Motivation	2.74	0 .45	3 .20	0 .58	0 .46	5.023	. 000
Science-related Career Aspiration	2.57	0 .69	3 .11	0 .72	0 .54	4.280	. 000
Science-related Attitude	2.82	0 .63	3 .35	0 .50	0 .53	5.231**	. 000
Overall	2.73	0 .46	3 .23	0 .50	0 .50	5.44	. 000

* : Test Statistic Z of Wilcoxon Signed-Rank Test (Negative Rank Sum: -268.00, Positive Rank Sum: 1007.00)
** : Test Statistic Z of Wilcoxon Signed-Rank Test Z (Negative Rank Sum: -184.50, Positive Rank Sum: 1090.50)

Satisfaction with Science Classes Utilizing Smart Devices

Perception of the Effectiveness of Using Smart Devices in Science Classes

Out of 60 students surveyed, 56 responded, excluding those who participated in other activities. The results are presented in Table 4. The proportion of students who perceived the use of smart devices in science classes positively (Agree, Strongly Agree) was over 91.1% for all survey items. The overall average value, converted to a 5-point scale, was also high at 4.64.

Among the items related to the effectiveness of using smart devices in science classes, students recognized 'satisfaction with science classes using smart devices (4.80)' and 'increased interest in classes compared to other subjects (4.79)' as having high effectiveness. 'Individualized learning (4.52)' and 'improvement in science skills (4.54)' were slightly lower than other items but still represented high values. This suggests that smart devices have had a positive impact on students' science learning.

Table 4. Perception of the effect of using smart devices in science classes

Number of Responses by Reaction Type (%)						Average Value	
Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	M	SD
Enhancement of satisfaction with science classes	0	0	1 (1.8)	9 (16.1)	46 (82.1)	4 .80	.44
Enhancement of interest in classes compared to other subjects	0	0	1 (1.8)	10 (17.9)	45 (80.4)	4 .79	.46
Improvement in science skills	0	0	5 (8.9)	16 (28.6)	35 (62.5)	4 .54	.66
Individual customized learning possible	0	1 (1.8)	4 (7.1)	16 (28.6)	35 (62.5)	4 .52	.71
Improvement in the ability to use digital devices	0	1 (1.8)	5 (8.9)	9 (16.1)	41 (73.2)	4 .61	.73
Enhancement of communication	0	0	5 (8.9)	12 (21.4)	39 (69.7)	4 .61	.65
Overall Average	0	0.3 (0.6)	3.5 (6.3)	12 (21.4)	40.2 (71.7)	4 .64	.52

Advantages and Disadvantages of Science Classes Using Smart Devices

The types of responses students gave as advantages of science classes using smart devices are presented in Table 5. The most common advantages described were 'better understanding through the use of various programs (25%)' and 'classes are fun (25%)'. Additionally, 'being able to search for unknown topics immediately (17.8%)' and 'convenience of using Chromebooks (14.3%)' were also highly noted. Other advantages included 'access to class content in various forms, improved concentration in class, preference for not writing by hand, ease of collaboration through group work, and enhanced ability to use various programs’. Therefore, it can be seen that smart devices provide students with various conveniences, increase interest in learning activities, and contribute to active participation in classes.

Table 5. Advantages of science classes using smart devices

Rank	Response Type	Number of Responses (%)
1	Understanding well by using various programs (Digital Textbooks, Google surveys, Quiz N, etc.)	14 (25.0)
1	The class is fun	14 (25.0)
3	Can immediately search for what I don’t know	10 (17.8)
4	It’s convenient to use a Chrome book (p.c.)	8 (14.3)
5	It’s good to be able to access the class content in various forms (videos, programs)	4 (7.1)
6	Concentration is good	2 (3.6)
6	It’s good to use a Chromebook without writing by hand	2 (3.6)
8	Collaboration skills have been enhanced through sharing and joint work	1 (1.8)
8	The ability to use a Chromebook and various programs has improved	1 (1.8)
	Total	56 (100.0)

The types of responses students gave as disadvantages of science classes using smart devices are presented in Table 6. Most students reported ‘none (53.6%)’ as a disadvantage. The main disadvantages noted were ‘students accessing other programs or sites during class time (19.7%)’ and ‘time-consuming to learn how to use devices and programs (10.7%)’. Other inconveniences included ‘lack of a mouse or earphones, eye strain, poor internet connection, and time-consuming tasks’.

Table 6. Disadvantages of science classes using smart devices

Rank	Response Type	Number of Responses (%)
1	None	30 (53.6)
2	There are students who access other sites during class time.	11 (19.7)
3	It takes time to learn how to use the device and program.	6 (10.7)
4	It’s inconvenient without a mouse, earphones, etc.	3 (5.4)
4	Eyes (vision) hurt	3 (5.4)
6	Internet connection is poor.	1 (1.8)
6	It takes a lot of time.	1 (1.8)
6	Games don’t work.	1 (1.8)
	Total	56 (100)

Discussions

This study demonstrated that student-centered science classes utilizing smart devices positively affected the cultivation of core science competencies, enhancement of positive science experiences, and improvement of class satisfaction. The following discussions can be made in relation to these results:

Firstly, the use of smart devices in science classes improved students’ self-perception scores of core science competencies. This confirms that active participation in teaching and learning activities using smart devices in science classes is more beneficial for fostering core science competencies than traditional science classes. Notably, the most significant improvements were observed in problem-solving and communication skills, suggesting that the use of smart devices is a useful teaching method for enhancing these skills emphasized in science education. These findings are consistent with studies indicating the effectiveness of computer-based science inquiry programs in chemistry classes (Kim & Kim, 2022) and that students' core science competencies can manifest in context and problem situations (Chae & Noh, 2015). Therefore, teachers need to create problem situations that require the use of smart devices in science classes and guide students to use smart devices appropriately within the class context (Dimitriadou & Lanitis, 2023).

Secondly, the student-centered science classes using smart devices showed statistically significant improvements in areas corresponding to positive science experience indicators compared to before the use of smart devices. These results align with research suggesting that science classes utilizing computers, smart devices, digital textbooks, and artificial intelligence are effective in enhancing positive science experiences (Kim & Kim, 2022; Sung, 2023; Yeo & Shin, 2022; Yun et al., 2015). Thus, it can be suggested that smart devices enable students to have various positive experiences in science classes. Among the areas of positive science experience indicators, 'aspirations for science-related careers,' 'attitudes towards science,' and 'emotions in science learning' showed significant improvements and are closely related to interest and enthusiasm for science, as well as recognition of the importance and value of science (Kim & Kim, 2022). This implies that the use of smart devices in science classes is highly effective in the affective domain for students. It is known that primary, middle, and high school students' values in positive science experience indicators decline due to the difficulty of science content and the monotony of classes (Kim et al., 2022). In this regard, the use of smart devices during science classes suggests a useful tool for engaging students' interest. However, smart devices alone cannot attract students' interest. Convenience and fun can be provided to students when useful apps and platforms are available and utilized in classes (Wen & Mi, 2024).

Thirdly, the satisfaction scores and descriptive content regarding science classes using smart devices indicate that students are very satisfied with the use of smart devices in science classes. The use of smart devices has been found to stimulate interest in class activities, increase class participation, alleviate boredom, and improve attitudes towards classes (Dimitriadou & Lanitis, 2023; Li & Liu, 2023; Shraim & Crompton, 2015; Song & Jeong, 2023). Additionally, the use of various educational applications implemented through smart devices provides convenient assistance in learning activities and helps in understanding the content (Yun et al., 2015; Wen & Mi, 2024). Information literacy and the ability to use mobile devices are necessary to provide students with sufficient learning experiences and lead to learning effectiveness (Dimitriadou & Lanitis, 2023; Pinto et al., 2022). Therefore, the regular use of smart devices by students naturally improves their ability to use smart devices (Chang & Joung, 2017) and is useful in increasing satisfaction with classes (Jung, 2024). The use of smart devices and related programs facilitates collaboration among students, thus confirming their usefulness in enhancing collaborative skills (Jang & Park, 2014).

Fourthly, while there are many positive effects of using smart devices in science classes, students' responses describing the disadvantages indicate instances of using smart devices for purposes other than learning activities. This highlights the need for caution as the use of smart devices, digital textbooks, and apps can lead to student disengagement from classes and negatively impact class concentration and face-to-face interactions among students (Choi et al., 2012; Han, 2014; Yun et al., 2017). To prevent this, sufficient pre-education and continuous guidance on the use of smart devices should be provided to students. Additionally, teachers need to establish the intent of using technology like smart devices in classes and develop teaching and learning strategies to promote students' use of technology (Kim & Chung, 2017; Yun et al., 2017).

Conclusions and Implications

This study examined the effects of student-centered science classes using smart devices in a flipped classroom format through a case study in a school setting. To this end, a student-participatory class using smart devices was conducted for 30 sessions (approximately one semester) with 60 male students from three classes at C-Middle School, and the effects on science core competencies, positive science experiences, and class satisfaction were analyzed through pre- and post-perception surveys.

The educational implications and conclusions drawn from this are as follows:

First, student-centered science classes utilizing smart devices can contribute to the enhancement of students' science core competencies. Significant improvements were observed especially in scientific problem-solving abilities, and there were also relatively high enhancements in scientific communication skills and scientific inquiry abilities. These positive changes support the argument that the use of smart devices in science classes is beneficial for cultivating students' core competencies.

Second, the use of smart devices in science classes increases students' interest and engagement in science. By participating in science classes using smart devices and useful educational apps, significant effects can be achieved in various areas of positive science experience indicators, including 'science-related career aspirations,' 'attitudes towards science,' and 'emotions in science learning.'

Third, the diverse educational uses of smart devices have increased students' satisfaction with science classes. Students perceive that using various learning programs with smart devices not only makes classes enjoyable but also aids in understanding the material.

In summary, allowing students to directly use smart devices and various learning programs can lead to an interest in science classes and active participation in teaching and learning activities, thereby fostering the cultivation of science core competencies and enhancing positive experiences in science.

The educational implications that can be derived from this study are as follows:

First, using smart devices in science classes suggests a useful teaching and learning strategy that can enhance students' interest in science classes and encourage active participation in class activities. Especially in the era of the Fourth Industrial Revolution, the use of smart devices and various educational apps in the field of science education implies that students' learning experiences can be enriched and learning outcomes improved.

Second, to cultivate students' science core competencies and promote positive experiences in science through science classes, it is suggested that operating classes using smart devices is an effective teaching and learning strategy rather than teacher-centered lectures. Especially in the current era where the use of AI/SW is rapidly increasing, science classes utilizing smart devices should be further activated to prepare for future society.

Third, to prevent potential dysfunctions that may arise when students use smart devices during class, sufficient prior education is necessary for students to become familiar with the use of educational apps and programs. Additionally, efforts for teachers' guidance and management to use smart devices appropriately and beneficially in teaching and learning activities are essential.

While this study demonstrates the potential of education using smart devices, there were limitations in revealing the effects of classes using smart devices due to the nature of school field research, such as setting up control groups or applying various class models differentially. As the Green Smart Future School (MOE, 2021), which includes the use of artificial intelligence (AI), is currently being promoted, future research is expected to continue on teaching and learning strategies and effects using smart devices and AI, considering various learning environments and individual characteristics of students.

Conflicts of Interest

The author(s) declared no conflicts of interest.

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