KIEAE Journal, Vol. 22, No. 6, Dec. 2022, pp.45-56.

KIEAE Journal
Korea Institute of Ecological Architecture and Environment
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User-Participatory Design of Green Smart Future Schools Using a Design Thinking Process and Big Data Analysis Technique

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ABSTRACT

Purpose: The Ministry of Education announced 'Green Smart Future School' in 2021, which is a representative project of the Korean New Deal. It was selected as a priority from the 'School Space Innovation Project' by the Ministry of Education in 2019. It is based on continuing the basic principle of a 'Student-Centered User-Participatory Design'. However, the lack of a design process centered on the facilitators, who are the key participants in the design, as well as the distinct clustering of design toolkits has led to repeated design workshops. In addition, it is impossible to determine the relevance in the opinions and results presented by the many participants, thus school space user (Students, Parents, Teachers) rely solely on the facilitators. **Method:** For this study, the 'Design Toolkit' and 'Service Design Thinking' decision-making tools were clustered. Further, 'Text Mining' and 'Word Cloud' were used for big data analysis using the Python software. Finally, this design process and data analysis methodology were performed after selecting actual participating design schools. **Result:** Significant results were obtained when collectively considering the agreement between the proposed construction images, derived opinions, and satisfaction.

KEYWORD
디자인싱킹
텍스트마이닝
그린스마트미래학교
빅데이터
학교공간혁신

Design Thinking
Text Mining
Green-Smart School of the Future
Big Data
School Space Innovation

ACCEPTANCE INFO
Received Oct. 17, 2022
Final revision received Nov. 9, 2022
Accepted Nov. 14, 2022

1. Introduction

1.1. Background and Objectives

On February 3, 2021, the Ministry of Education announced the 'Green-Smart School of the Future', a flagship project of the Korean New Deal[1]. This project aims to improve school facilities (space) directly related to education by school units, which have dilapidated over the past 40 years. Approximately 18.5 trillion won are to be invested over 5 years to newly build or renovate 2,835 school buildings at 1,400 school sites. The four key components of the project are as follows: a "Green School" targeting low carbon emissions and zero energy buildings, "Smart Classroom" based on the state-of-the-art internet and communication technology (ICT) enabling future-oriented teaching and learning, "Space Innovation" through student-centered user-participatory design, and "Development of School Facilities into a Complex," thus interconnecting living social overhead capital (SOC) with local communities. Here, "Space innovation" refers to implementing the basic principles of the "student-centered user-participatory design" of the School Space Innovation Project, which has been promoted as a key program of the Ministry of Education since January 2019.

In the Green-Smart School of the Future project, unlike the existing facility-oriented projects with the simple replacement of facilities and a supplier-centric, monotonously unified, and fixed space design, "classrooms enabling various classes with the stimulation of imagination and a break area and learning space with an open, creative, and emotional design" are newly created through space innovation based on a design of the participatory school users (students, faculty, parents, local residents). Thus, using such creative space designs and configurations, this project will culminate in the innovation of curriculums for the nurturing and development of talents, which is suitable and prepared for the future society.

In the space innovation project of the Green-Smart School of the Future, a facilitator with architectural knowledge and experience is selected to manage and supervise the overall process of the participatory design, including facilitating the effective communication between the needs of school members and users, their opinions regarding the design and of those involved in building and renovation work, and thus plays an integral role in this project. However, although a range of participatory design operation manuals have been presented,including design toolkits, a decision-making tool, and design cases, to enhance the expertise of the facilitators' participation, no clear clustering of

pISSN 2288-968X, eISSN 2288-9698
https://doi.org/10.12813/kieae.2022.22.6.045

the design process and design toolkits suitable for individual purposes has been established, resulting in repeated design workshops. In addition, unlike the design for general buildings, the School Space Innovation Project relies solely on the facilitator because the suitability of the opinions and results derived is unknown without a proper evaluation despite having several participants in the project.

If the School Space Innovation Project is implemented in the supplier-centric manner, as in the existing design methods, an efficient reflection of a wide range of opinions and needs of the participants would be difficult to obtain, and thus the demand and expectations of the users relative to the space design would not be fulfilled. Therefore, this study aims to establish a step-by-step process for the user-participatory design and cluster design analysis decision-making tools. In addition, we aim to identify a digital analysis methodology that provides a quantitative guidance and is implemented in the efficient design of the innovative school space. In this manner, rather than simply focusing on exterior changes through the finishing of materials in the dilapidated school spaces or renovating the individual characteristics of spaces, this study aims to present a novel platform of school space design through new approaches, such as user-centered pragmatic processes and data analyses.

1.2. Methods

This study is conducted using the following research methodologies:

(1) [Design process] The main aim of the user-participatory design is to derive an understanding of the project, user needs, and requirements through workshops, where decision-making design toolkits are used to reflect effective and rational process plans. In this study, these design toolkits are introduced and clustered with the design process of the Service Design Thinking.

(2) [Digital data analysis methodology] In the era of ICT, data analysis has emerged as an important technical factor. A significant amount of unstructured data is to be analyzed in this study; thus, converting the data for efficient utilization and establishing standards are necessary. In addition, the analysis of personal predicates, such as wishes and expressions of emotions in sentences, requires a tokenization process to separate sentences into individual words. For digital analysis methodologies to analyze participants' data, we propose analysis methodologies of "Text Mining" and "Word Cloud."

(3) [Participatory design process] With the design process and digital data analysis methodologies presented earlier, by selecting an actual school site for the School Space Innovation Project, a "design process" for each step was utilized in the workshop, and the products of each step in the design process were derived using the "digital big data analysis methodology" and applied to the participatory school space design.

2. Theoretical Background

2.1. Establishment of user-participatory design process

1) Service Design Thinking

"Service design thinking" is a term based on the combination of "service design" and "design thinking." It refers to a user-centered mindset, which organizes the tools and methods (processes) necessary for application in the field of design practice beyond a theoretical understanding and provides participants having different perspectives with various methods and tools. The concept of service design, which originated in the public service industry owing to G. Lynn Shostack in the UK in 1982, now encompasses the design required in all service areas and is based on the understanding and analysis of users. In the "service design thinking" process, the first half focuses on empathy to identify the needs of the customers (users), and the second half mainly focuses on prototyping for concept development. By reducing these stages in the process, "service design thinking" describes the continuous exchanges with unending iterations between the diffusion and convergence steps.

Based on the theory of the "service design thinking process" (SDTP), which is utilized as a methodology to derive innovation, a previous study[2] introduced a 6-step process as follows: (1) understanding, (2) observing, (3) analyzing, (4) proposing an idea, (5) making, and (6) growing. Thus, this 6-step process can be used or reconstructed to be used as a methodology in this study.

2) Double Diamond Model

Considering the methodologies for the utilization of design thinking, the "Double Diamond design process model" (Design Council, UK, 2005)[3] is widely used in the field of service design. The Double Diamond model, as shown in Fig. 1., demonstrates the connection of two diamonds composed of the diffusion and convergence steps described above; it is the most basic process in the methodologies of problem solving.

Another previous study[4] describes the two diamonds as follows. The first diamond of the connected Double Diamond model indicates the "discover" and "define" steps, representing a social science approach for finding problems and understanding the empathy between individuals and buildings. The second diamond model indicates the

"develop" and "deliver" steps, representing the process of forming ideas, finding and selecting solutions, and finalizing concepts and ideas to create solutions. In the basic process, a range of different analysis tools (design toolkits) are used for considering the diverse interests of the participants. For the application of the design toolkits, the processes can be reconstructed for each step in design thinking. The names of the design thinking processes are mainly presented in terms of words expressing actions and end with "~hagi (means "doing" in Korean), such as "understand-hagi," "apply-hagi," or "verify-hagi," to help the participants understand. The most basic and general suggestion of the process involves steps five to seven, depending on the process of implementation and the agency of process development. In this manner, the identified problems of the participants are addressed at each step.

A previous study[5] defined the concept for the respective steps, which are summarized in Table 1., considering the user participatory design. Although there may be differences in perspectives depending on the type of problems to be solved, the design thinking process proceeds by an iteration of the diffusion and convergence as described in the Double Diamond model.

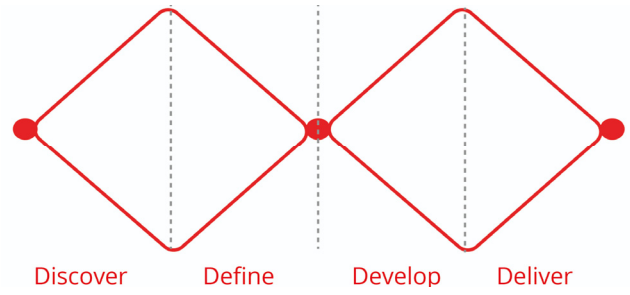


Fig. 1. The 'Double Diamond' Design Process Model

Table 1. Container box dimension for ISO

Process	Step	Concept
Diffusion	Discover	• Investigation of required space and idle space, etc. • Information gathering steps to understand existing problems
Converge	Define	• Gathered information based on issues • Reviewing and establishing the space use needs of participants by providing related similar information
Diffusion	Develop	• Discover creative ideas and concepts for problem solving • The stage of judging the possibility of an idea and developing it into a specific design
Converge	Deliver	• Realistically reflect the derived design • Steps to improve through user review and finally provide it

2.2. Data analysis methodologies

1) Text mining

Text mining is often referred to as text analytics and consists of the combination of text and calculations (analysis). It is the process of information retrieval and analysis from text in which written resources from two different areas are used to extract useful patterns from large quantities of documents. Text mining is mainly used for generating knowledge by extracting patterns and relationships from text with unstructured data composed of natural language[6]. In text analysis, linguistic structures are organized into patterns through the process of decomposing sentences into nouns, postpositions and particles, and adverbs, which are the smallest syntactic units that deliver meaning, to extract the meanings of sentences. In addition, text mining allows the reconstruction of text data with a focus on keywords through preprocessing, which filters "Stopwords" that have little value in terms of extracting useful information.

2) Word Cloud

"Word Cloud," commonly referred to as textcloud, is a text data visualization technology that allows the visual representation of words according to their importance based on the frequency of each word used[7]. A word cloud extracts repeatedly appearing text data, displays text appearing more frequently in a large font, and that appearing less frequently in a reduced font. This method allows the analysis of important words. In addition, a word cloud allows the organization and representation of text data around keywords and visually highlights them using random colors. Fig. 2. illustrates a word

Fig. 2. SCIENCE ON 'Word Cloud'

cloud demonstrating the automated visual representation of keywords recently searched in ScienceOn[8], an integrated service of science and technology knowledge infrastructure that provides research data and information analysis services.

Recently, techniques, such as word clouds and text mining, are widely being employed as one of the big data analysis methods for handling and processing vast amounts of information. Certain easy-to-use software that can be applied without using complex programming languages are available, such as Orange 3.0, which allows overcoming language barriers in programming and are mainly used in ICT technology and electronic engineering,such as computers. However, unlike English, the Korean language of hangul consists of agglutinative morphology that uses various propositions, and the tokenization process of Korean words is highly complex compared to English; therefore, there is a limitation in applying software, such as Orange 3.0, which allows easy access without programming languages.

Accordingly, for the user-participatory design that uses Korean sentences as models, an appropriate programming language software needs to be selected for data analysis.

In this study, a software based on Python, which is one of the computer program languages, was used to perform the analysis using text mining and visualization with a word cloud.

3. Clustering of user-participatory design process

3.1. Development of design thinking process

In this study, the existing six steps introduced as the basic steps of the design thinking process were reconstructed as follows: "(1) understand, (2) explore, (3) imagine, (4) adorn, (5) look back, and (6) value".

Details regarding each of the steps in the process are as follows.

Step 1: [Understand] This step indicates the time required to introduce the user-participatory design, understand and identify the problems in the existing school space, and "to investigate the spaces need" in the school.

Step 2: [Explore] The direct sketching and observation of the space is conducted in Step 2, wherein the space needs and utilization investigated in Step 1 are analyzed to determine the keywords and develop a basic conception of the space.

Step 3: [Imagine] According to the space design set in Step 2, specific individual spaces are developed in 3D to reflect the "participants' realistic opinions regarding the space" that were previously recognized.

Step 4: [Adorn] The data collected up to the previous steps are shared in this step to confirm the design principles and areas. Further details regarding the space are presented through the basic design and "discussion on the scope of the design" to be adorned in the applicable space, establishing the priorities of the School Space Innovation Project.

Step 5: [Look back] In Step 5, practical space design ideas are derived and evaluated. According to the set design plan, 3D design tools are used to present the conception of the space, and "review the results of the design" that have been developed up to this step.

Step 6: [Value] In this step, the final space design plan is derived through the review opinions collected through Step 5, and design quality indicators (DQIs) are used to "perform the satisfaction survey and derive implications." Based on the findings of the survey, this is a finalization step that leads to the real design implementation and construction.

3.2. Utilization of Design Toolkits

In the user-participatory design, there is a difference in the quality of the deliverables derived depending on the level of active engagement and collaboration of participants. Therefore, to facilitate a collaboration including the engagement of participants, a design thinking process and appropriate analysis tools are required. The facilitator can utilize the design thinking process and analysis tools to help the participants effectively address the problems, and for process-oriented user participation workshops that emphasize on "how" rather than "what" for activities to achieve the desired objectives of the design. In all the workshop processes, a "Workshop Operation Manual for the School User-Participatory Design (2012)"[9] was used to understand and analyze the space design including creative ideas, and eight types of decision-making tools (design toolkits), as shown in Table 1., were applied to the six-step process introduced earlier.

The design toolkits that were composed as indicated above are summarized using the decision-making tools in the Workshop Operation Manual (2012); the details of each toolkit are outlined as follows.

1) Padlet

Padlet is a tool used in online classes; it is a web application in which class participants can connect to one workspace and upload, post, and share memos and other information[10]. In addition, the padlet enables various means to communicate and collaborate through linking and uploading/posting media and audio files as well as images. Owing to the high compatibility with mobile devices, user accounts can be easily created and the participants can freely work through the padlet link without having to install the application. This tool was used in Step 1 of this study for the survey of the space design.

2) Wish List

As shown in Fig. 3., in this step, the participants express their

wishes regarding the potential school facilities in writing, and can freely provide their answers using phrases given by the facilitator (or individual who developed these questions) regarding their feelings for the space, shapes, colors,and materials for the space. In this process, participants can develop a broad understanding regarding the range of the space rather than within standardized, uniform perspectives, and they can simultaneously present their wishes regarding a particular part of the space (wall, floor, ceiling, etc.) or the shapes of the space. The "wish list" serves as a reference for selecting the topics and method for organizing a full-scale workshop.

3) Design Card

The design card is a tool in which the facilitator selects topics that are most likely to be issues in the space design, investigates the type of space in advance, and presents the type of spaces as images. Participants can select the design in the school space or the type of school supplies and items, such as furniture, through images, leading to advantages of being able to broaden the input and consider the perspectives of non-major participants.

4) Design Game

While the design card described in the previous section refers to selecting images presented by the facilitator, in the design game step, the participants select the images. In this process, the facilitator presents a suitable empty workspace in a basic format, and the participants can search their desired images using a tablet and attach them to the empty space presented by the facilitator.

5) Future Classroom Drawing

In the future classroom drawing step, each participant or team draws a picture in the space using visual data, such as the design cards and photos from the design game. At this time, the facilitator allows participants to draw a planar or three-dimensional picture by presenting an appropriate area of empty space in advance, as in the design game step, to provide limits for expressing the imagination of the participants, which would have boundless cases of expressions otherwise.

6) Collage/Space Discussion

In the collage/space discussion step, based on the data discussed thus far, images to be reflected in the design are placed in the relevant space using the analyzed data. This process allows an increased reflection of the reality of the design considering that the process is conducted based on the actual space to be used, which includes the actual design and items to be reflected in the project. Thus, participants can proceed with a more detailed discussion for the space through these images. Therefore, the collage space discussion step provides an opportunity where the facilitator can explain how well he or she understood the wishes of the participants, as well as a time for the participants to understand the direction of the design development in detail.

7) Weighing

During the weighing step, the facilitator reviews the design development and introduces the space with 3D images by reflecting the opinions presented in the previous step of the space discussion. Because the spatial scale is not reflected in the collage/space discussion step, the number, design, and color of items to be placed in the actual space, such as furniture, is discussed in the weighing step.

8) Design Quality Indicator (DQI)

DQI is a step for design quality management where the participants analyze and evaluate the design proposal and express their opinions. It is similar to the existing, commonly used method of surveys; however, because the evaluation is divided by different types of spaces and an evaluation of the plan conforming to the design is conducted, more detailed and specific questions should be derived from this step.

3.3. Clustering of design process and design toolkits

In collaboration with the participants, the process may become tedious if several tasks are conducted on a single day; therefore, the six analysis tools described above should be suitably separated and offered to the participants. Thus, the key concepts for each of the four steps of the Double Diamond model were

Table 2. Design Process

Step	Process	Analysis Equipment	Utilization
Discover	Understand	(1) Padlet	• Understanding the Problem
Define	Explore	(2) Wish List (3) Design Card	• Set Keywords • Basic Idea
	Imagine	(4) Design Game (5) Future Classroom Drawing	• Specific Ideas • Understanding of Space
Develop	Adornment	(6) Collage	• Space Discussion
	Look back	(7) Weighing	• 3D Image Review
Deliver	Value	(8) DQI	• Final Plan • Design Evaluation

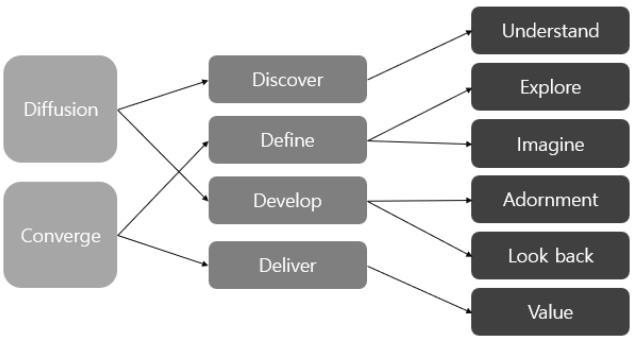


Fig. 3. Design Process Clustering

clustered into the six processes shown in Table 2. and Fig. 3.

In the 'Discover' step, which is the first step in the Double Diamond model, the application padlet was used to investigate the required and idle spaces to be implemented for future workshops.

In the 'Define' step, the second step, various tools,such as Wish List, Design Card, Design Game, and Future Classroom Drawing are used to actively gather the opinions of participants to discover and organize the needs and issues in the space usage, as well as creative ideas.

In the 'Develop' step, the third step, participant opinions are shared through a facilitator and are developed into specific designs. The collage/space discussion and weighing are performed during this process for an analysis of the ideas derived in the Define step, and detailed discussions are conducted using images (photos, 3D) prepared by the facilitator.

In the 'Deliver' step, the final step, DQI is used for the evaluation of the satisfaction of the participants, including the overall direction of the design and detailed contents.

4. Application of user participatory design

4.1. Overview of the participatory design school site

As the target school for the user participation project, a public elementary school in Sejong Special Self-Governing City was selected, which opened in September 2020. The school is a three-story building with 27 classes, 39 faculty members, and 574 students as of March 2021. The building area is approximately 6,426㎡ on the first floor, 5,241㎡ on the second floor, and 2,722 ㎡ on the third floor, excluding the basement, and the school is constructed as a low-story structure.

Preliminary planning was simultaneously conducted online and offline. The participants in the online planning session were as follows: 44 students, 12 teachers, and 26 parents. The offline participants consisted of only 22 students owing to the special circumstances of the COVID-19 pandemic in 2021.

4.2. Schedule of participatory design process

The workshops for the participatory design were conducted both online and offline from March 2021 to June 2021. Based on the previously developed design process, the frame for the design was set according to the purpose of the design, and the schedule including the design toolkits to be used according to the process is presented in Table 3.

Table 3. Participatory design Schedule

No.	Step	Date	Process
1	Discover	03/10~19	Understand
2	Define	03/31	Explore
		04/14	Imagine
3	Develop	05/12	Adornment
		06/09	Look back
4	Deliver	06/21	Value

4.3. Analysis of participatory design data

The results of the workshops of the target school site for the participatory design project were all collected as text data and analyzed accordingly. Regarding the data analysis methods, the previously introduced text mining techniques and word clouds were used. In this study, the text mining process is introduced only in the first step of the workshop (Discover); for the subsequent steps, considering the redundancy in the description of the study, only the analysis of the participatory design results was compiled and presented.

5. Analysis of user participatory design data

5.1. Conception of user participatory space design (Discover)

1) Data collection

The "Discover" step is a process for "Understanding," and padlets were used as the tool in this step. The opinions of the participants were collected and organized as data, which is shown in Table 4.; the number of data and sentence lengths were analyzed as shown in Table 5. A total of 82 opinions were utilized;as a result of a simple statistical analysis of the sentence length, the average sentence length was 40.98. Although it is not possible to select an appropriate limit

Table 4. Opinions List

No.	Opinions (Sentence)
1	I think it would be a good place to borrow school supplies or supplies when you don't have them.
2	It would be nice to have a space where I can study.
3	After-school space for children who missed out on after-school applications
4	I think it would be nice to have a meeting space where students can wait.
5	I wish I had a room where I could de-stress.
6	I wish I had a personal study space.

Table 5. Sentence Length

No.	Step	Value
1	All training data	82
2	Maximum sentence length	243
3	Minimum sentence length	2
4	Average sentence length	40.98
5	Sentence length standard deviation	40.91
6	Median sentence length	27.5
7	Sentence length 1st quartile	15.0
8	Sentence length 3rd quartile	52.75

Fig. 4. Wish Word Cloud

for the length, the number of words reduced during the word tokenization process will be an important consideration factor.

If the data collected up to this step is visualized using a word cloud, it is illustrated as shown in Fig. 4.

2) Data analysis

For the existing model (sentences) composed of unstructured data, stopwords need to be manually added to arbitrary source codes through the Stopword Set ([DB]). In addition, while repeating the execution of the program, stopwords are found and added into the code. To extract meaningful words from these sentence data, word tokenization was performed, as shown in Fig. 5.

Among the contents written in the padlet, words describing personal styles of endings with euphemistic language (“~좋겠어요’, ‘~좋을 것 같아요’, ‘~~ 했으면 좋겠습니다’, ‘~~ 이면 좋을 것 같습니다”: Korean endings indicating “~would be good,” “might be good,” “could be good,” etc.), general words related to the project characteristics, such as “space” and “room”, and other expressions, such as connective words and postpositions (“~은”, “~는”, “~에”, “~을”, “~를”, “~위한”), underwent preprocessing, and the text data were divided into words and sentences for analysis.

In summary, as shown in Table 6., a total of 70 words consisting of the following were derived based on the aforementioned analysis of the text data: complex culture (5 times), pick-up (4 times), active class and indoor playground (3 times respectively), break, play, TV-room, kiosk, and sitting (2 times respectively), and afterschool, stress, slime, bookstore, conference room, swimming pool, etc. (once each). Comparing the number of total words in the initial analysis (82), the number of words was maintained through the process of analysis to a certain extent.

In addition, the analyzed frequency of words is summarized in Table 7. Compared to the sentences before word tokenization, the average sentence length was reduced from 40.98 to 4.67;the first quartile sentence length, indicating the value of the lower 25% based on the sentence length, was reduced from 15.0 to 3.0. In addition, the third quartile sentence length, indicating the value of the upper 75%, was also reduced from 52.75 to 6.0.

Table 6. TextMining Classify

No.	Word
5	Complex Culture
4	Pick-up (Wait)
3	Active Class, Indoor Playground, Counseling Center... etc.
2	Break, Quiet and Free, Play, TV-Room, Kiosk (Cafe), Sitting, Indoor Sport, Team Activity... etc.
1	After School Homework, Stress, Slime, Movie Theater, Bookstore, Conference Room, Swimming pool, Baseball field, Taekwondo center, Stationery store, Arcade... etc.
Total	70 words

```
stop_words=set(['은','는','이','가','하','아','것','들','의','있','되',
                '수','보','주','등','한','이나','을','없다','때','를',
                '에','하다','곳','위','때문','떨어지다','에는','있다',
                '공간','발','좋을 것 같다','했으면','좋겠다','위한',
                '없을 때','신청에','좋아하는','푸는','이나','후'])
okt=Okt()
clean_train_review=[]
```

Fig. 5. Text Stopword DB

Table 7. TextMining Analysis_Sentence Length

No.	Step	Value
1	All training data	70
2	Maximum sentence length	13
3	Minimum sentence length	2
4	Average sentence length	4.67
5	Sentence length standard deviation	2.18
6	Median sentence length	4.0
7	Sentence length 1st quartile	3.0
8	Sentence length 3rd quartile	6.0

Fig. 6. TextMining Analysis_Wish Word Cloud

Table 8. TextMining_Design Keyword

Space	Design Keyword
Break Area	Break, Stress, Counseling Center, Shop, Pick-up, Waiting
Learning Space	Classroom, after school homework, team activity, activity class
Cultural Space	Complex cultural, broadcasting studio, Movie Theater

3) Data optimization

The analyzed frequency of words was visually represented using a word cloud and is shown in Fig. 6. The sentence data was derived through text mining, which were optimized through

word tokenization. The optimization of sentences was conducted by a word-centered procedure and was set according to the target space by examining the relationship between the words. Words,such as baseball field, shopping room, vegetable garden, game room, swimming pool, and indoor playground, that have no direct relationship with the school spaces or cannot be realistically implemented, underwent a text filtering process at the discretion of the researcher. As a result, major spaces were largely classified into a "break area," "learning space," and "cultural space" for data optimization, as shown in Table 8. In this manner, in the conception of the space design (Discover) step, optimized spaces were selected and the subsequent process of the workshops was conducted based on the analyzed spaces.

5.2. Planning of user-participatory space design (Define)

The "Define" step is a process of "Explore" and "Imagine"; in this process, the Wish List for writing the wishes, Design Card for viewing and selecting images, Design Game for the participants to select images they wish for the space design, and future Class Drawing for directly drawing the design they wish, are the tools used for analysis. The future classroom drawing is differentiated from other communication tools because it actually involves drawings; however, as shown in Fig. 7., the text can be written in the drawing, or the researcher can view the drawing and express the content in the text to create a data model.

1) Break area

For the data used in the break area, word tokenization was conducted through text mining and was visualized using a word cloud,as shown in Fig. 8. A summary of the analyzed text data is shown in Table 9.

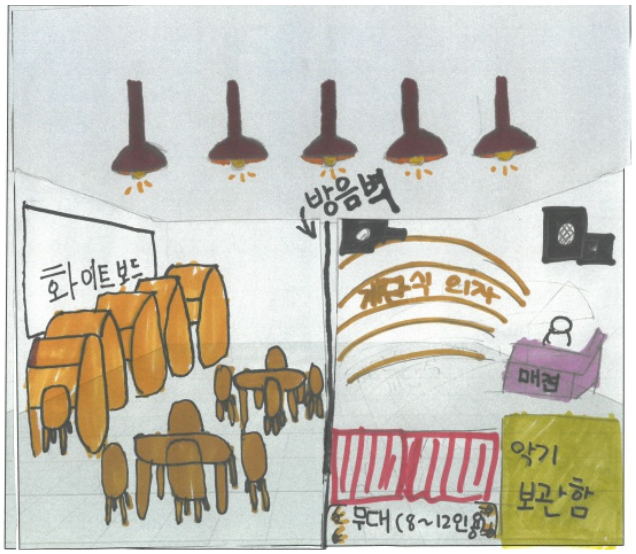


Fig. 7. Drawing the future class

The analysis demonstrated that there were a total of 70 words as follows: Chairs, cafe type, tables and chairs, etc. (17 times), sitting and reading (13 times), wood floor, etc. (10 times), storage of belongings, etc. (5 times), and mat floor, cascading chairs, and sedentary mix (3 times), tool storage (2 times), and pick up, safe walls, non-slip floors, etc. (once).

2) Cultural space

For the data used in the cultural space, word tokenization was conducted through text mining and was visualized using a word cloud,as shown in Fig. 9. A summary of the analyzed text data for the cultural space is shown in Table 9.

The analysis demonstrated that there were a total of 56 words as follows: wood floor, etc. (9 times), chair without a desk, etc. (7 times), tiled floor, etc. (6 times), chair and seat mix, etc. (5 times), storage of belongings, etc. (4 times), seating without desks, etc. (3 times), café table and chairs, etc. (2 times), and bookshelves etc. (once each).

3) Learning space

The data used in the learning space was visualized using the word cloud, as shown in Fig. 10. The analyzed data is presented in Table 11.

The analysis demonstrated that there were a total of 85 words as follows: desks and chairs in the same layout (16 times), tool storage type, etc. (10 times), sit and read, read a book, etc. (9 times), wood floor, etc. (4 times), meeting room, chair and sedentary mix, etc. (3 times), and storage cabinets, space without walls, etc. (2 times).

5.3. Proposal of user participatory space design (Develop)

The "Develop" step is an 'Adorn' and 'Look back' process, which reviews the requirements collected thus far. As shown in Fig. 11., participants can imagine and discuss the actual space by observing a collage prepared by the facilitator, and also discuss the design of the space, items, and colors by observing the 3D design images with the scale assigned.

Because this process is conducted based on images, the facilitator should lead the workshop to ensure that the words for each element can be extracted rather than evaluating the image quality to derive the text data as a result of this process.

1) Break area

The data used for the break area was visually presented using a word cloud, as shown in Fig. 12.; the analyzed data is presented in Table 12.

The analysis demonstrated that there were a total of 46 words

Fig. 8. Word Cloud_Break Area

Table 9. TextMining_Break Area

No.	Word	No.	Word
17	Cafe type, Chairs, Tables and Chairs	3	Mat floor, Cascading Chairs and Sedentary Mix
13	Read a Book without	2	Tool Storage
10	Wood Floor	1	Safe Walls, white Tables, Non-Slip Floors...etc.
5	Storage of Belongings		
Total	92 words		

Fig. 9. Word Cloud_Cultural Space

Table 10. TextMining_Cultural Space

No.	Word	No.	Word
9	Wood floor	4	Storage of belongings
7	Chair without desk	3	Seating without desks...etc
6	Tiled floor	2	Cafe table and chairs
5	Chair and seat mix	1	Bookshelves, safety, mats...etc
Total	56 word		

Fig. 10. Word Cloud_Learning Space

Table 11. TextMining_Learning Space

No.	Word	No.	Word
16	Desk Chair together Layout	4	Wood Floor
10	Tool storage type...etc.	3	Meeting Room, Chair and Sedentary Mix
9	Sit and Read, Read a Book	2	Storage Cabinets...etc.
Total	85 words		

Fig. 11. (Left) Collage, (Right) 3d image

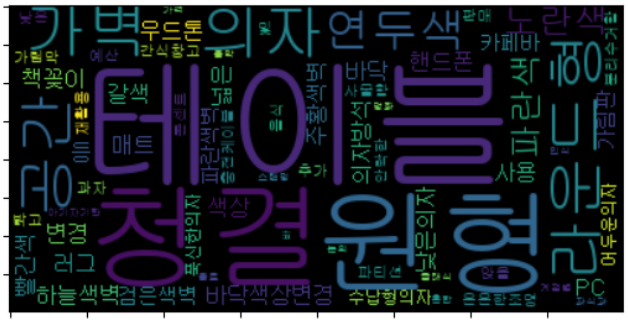


Fig. 12. Word Cloud_Break Area

Table 12. TextMining_Break Area

No.	Word	No.	Word
15	Table, Round, Table, Clean	4	Chair, Wall
11	Round type	3	Sky Blue Wall, Blue
7	Purple, Pink	2	Bookshelf, Wide Table...etc
Total	46 word		

as follows: Table, round, etc. (15 times), round type, etc. (11 times), yellow green, pink, etc. (7 times), chairs, temporary wall, etc. (4 times), sky blue, blue, etc. (3 times), and bookshelf, wall sockets, etc. (2 times).

2) Cultural space

The data used for the cultural space was visually presented using a word cloud, as shown in Fig. 13.; the analyzed data is presented in Table 13.

The analysis demonstrated that there were a total of 34 words as follows: Safety, space, expansion, etc. (9 times), curtains, problems, etc. (7 times), beam projectors, etc. (6 times), cushions, etc. (4 times), and transparent curtains, removable, etc. (3 times), and magnetic note, etc. (2 times).

3) Learning space

The data used for the learning space was visually presented using a word cloud, as shown in Fig. 14.: the analyzed data is presented in Table 14.

The analysis demonstrated that there were a total of 31 words as follows: Single room (16 times), glass booth (10 times), yellow space, etc. (9 times), glass materials, etc. (4 times), curtains, doors, etc. (2 times), and soundproof, open, yellow green, etc. (once).

5.4. Evaluation of user-participatory space design (Deliver)

An evaluation using the design quality indicator (DQI) was conducted. The questionnaire for the survey consisted of a total of 6 questions, and only 23 participants who attended the offline sessions of the participatory design participated in the survey. A total of 41 sentences were written in the other comments section.

As shown in Table 15., the questions for DQI are divided into the following areas: 1 Overall design (facilitated design) satisfaction, 2. Space seating design satisfaction, 3. Floor finish design satisfaction, 4. Space elevation design satisfaction, 5. Securing flexibility for various uses, and 6. Workshop satisfaction. The evaluation was based on a 5-point scale consisting of: "very satisfied, satisfied, neutral, dissatisfied, and very dissatisfied". As the analysis for the overall evaluation shown in Table 16. indicates, an average of 16.5 individuals selected "very satisfied," indicating satisfaction from 72% of the participants; an average of 5 individuals selected "satisfied", accounting for 22% of the participants. In addition, an average of

Fig. 13. Word Cloud_Cultural Space

Table 13. Text Mining_Cultural Space

No.	Word	No.	Word
9	Safety, Space, Expansion	4	Simple Wall Cushion
7	Curtains, Problems	3	Transparent Curtains, Removable
6	Beam Projector	2	Wood Floor, Magnetic Note...etc.
Total	34 words		

Fig. 14. Word Cloud_Learning Space

Table 14. Text Mining_Learning Space

No.	Word	No.	Word
16	Single Room	4	Glass Material
10	Glass Booth	2	Curtains, Doors
9	Yellow Space	1	Soundproof, Bookshelves...etc.
Total	41 words		

Table 15. Design Quality Indicator Question

Question	
1. Overall Design Satisfaction	- Is the design reflecting the user's opinion?
2. Space Seating Design	- Is it designed while considering walking and schooling?
3. Floor Finish Design	- Is the floor for each space designed while considering safety, cleanliness, and comfort?
4. Space Elevation Design	- Is the design designed to be creative and intimate?
5. Securing Flexibility for Various Uses	- Is it planned for multi-purpose use?
6. Workshop Satisfaction	- Are you satisfied with the workshop process?

Fig. 15. Word Cloud_DQI

Table 16. DQI_Satisfaction results

Satisfaction	Average (person)	Average (%)
Very satisfied	16.5	72
Satisfied	5	22
Neutral	1.5	7

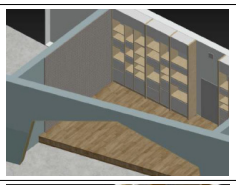
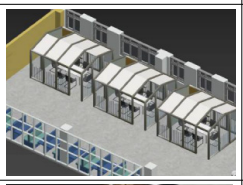
Type name	3d image	Constuction image		Text Data
Break Area				Cafe, Table, Chair, Sitting and Reading, Meeting, Wood floor, Storage of Belongings, Round Type, Pink, Yellow Green, Blue, Socket
				
Cultural Space				Wood Floor, Deskless, Tiled Floor, Mixed Chair Seating, Storage of Belongings, Beam Project, Magnetic Notes
				
Learning Space				Desk, Chair with, Storage of Tools, Storage Type, Sitting and Reading Books, reading a book, Mixed Chair and Sitting, Storage Cabinet, Light Green, Single Room, Glass Booth, Yellow Space, Glass Materials
				

Fig. 16. User-Participatory Design Results of the Green Smart Future Schools Using the Design Thinking Process and Big Data Analysis Technique

1.5 individuals selected "neutral," which is a minority of 7%.

Next, there was a section for freely writing other opinions, which were visually presented using a word cloud, as shown in Fig. 15. For this text model, because it does not aim for deriving results through the analysis of words, a text mining process was not conducted. The results demonstrated the inclusion of positive sentences, such as "would be good," "very," and "well," which is consistent with the aforementioned result of "very satisfied" in the satisfaction survey. In addition, in line with the aforementioned survey result of "satisfied," certain words with meanings between positive and negative nuances were expressed, such as "a little," or "I would like/will be better."

6. Conclusion

In this study, digital data analysis methods including conceptual processes of communication tools were used to present a platform for the user-participatory design of the School Space Innovation Project under the Green-Smart School of the Future School initiative. As a result of the study, three types of required spaces were selected through the "Discover" step. Subsequently, based on the selected spaces, in the "Define" step, four types of design toolkits, which are communication tools, were used to derive the requirements and needs of the users for the space design. Next, in the "Develop" step, the proposed requirements were organized by the facilitator for discussion in the workshop and additional matters for opinions were also derived. Finally, in the "Deliver" step, the final design images were reviewed and the satisfaction according to the space was evaluated.

Comparing the opinions derived from the early (Discover), middle (Define), and the later (Develop) process stages, the initial stage of the process mainly consisted of expressions of wishes from the participants,such as "I would like to~." In the middle stage of the process, these opinions were developed into words representing actions, such as "sitting" or "book reading";

furthermore, the word elements were expanded and became more specific, such as “single room,” “glass booth,” “glass material,” and “wall sockets.” As a result of the data analysis, the constructed images in Fig. 16. demonstrate that the opinions of the participants were effectively communicated and reflected.

In the space innovation project, for which the goals may differ depending on the users of the space, the steps of the design process derived in this study may not be standardized. However, the findings of this study present significant contributions in terms of presenting a new platform for the design of a school space through a user-centered pragmatic process with decision-making tools and new data analysis methods, such as the digital data analysis with a focus on understanding the participants, rather than the mere renovation of dilapidated spaces through the replacement of internal finishes or a simple change of objects,such as furniture.

The results derived in this study are expected to have contributions beyond the individual level, such as the existing participation process and methods, and present a theoretical framework in terms of the operation method. The proposed processes and steps can be developed into a systematic and practical tool that allows a participant-centered design rather than a designer-oriented design.

Acknowledgement

This research was funded by the National Research Foundation of Korea (Grant No: 2021R1A2C1014274).

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