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IMPLEMENTATION OF DESIGN BASED LEARNING FOR THE DEVELOPMENT OF SDGs EDUCATIONAL GAMES

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Abstract

Education on sustainable education (ESD) is gaining momentum to ensure that SDGs are met by 2030. The educational institutions have significant role in fostering ESD. However, there is lack of educational resources to be used for ESD. Particularly, teaching the concept of SDGs needs an attention grabbing and engaging approach and Design Based Learning (DBL) holds much potential. The main objective of this investigation was to describe the development of SDGs education resources i.e., SDGs educational games using DBL approach. Besides, the generic skills of the students during DBL were assessed during game development phase. The outputs of DBL were Bingo Mat game, Carrom board game and Sugoroku game. These games were validated for their effectiveness as resource for teaching and learning SDGs. The results revealed the positive impact on the generic skills of students through DBL during game development phase. Moreover, the response results of the players highlighted that carrom board game offered them the gaming experience while Bingo and Sugoroku offered them learning experience. Another important finding of this study is the need to teach SDGs from the younger age as the level of education had significantly impacted on their knowledge about SDGs. The results of this study will contribute to the domain of ESD by articulating an alternative pedagogy of integrating DBL with SDGs as invigorating educational resources and faculty development method.

Keywords – Design based learning, Education for sustainable development, Games, Generic skills, SDGs.

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1. Introduction

Educational institutions are the center for generation of new knowledge. Tremendous efforts have been made to promote Education on Sustainable Development (ESD) in educational institutions of Japan (Japan National Commission for UNESCO, 2016). ESD is the transformative pedagogy that fosters the key competencies needed for promoting sustainable development (Rieckmann, Mindt & Gardiner, 2017). In order to assure that SDGs are met by 2030, Japan has established the "SDGs Promotion Headquarters" under which "Sustainable Development Goals (SDGs) Implementation Guiding Principles" are formulated and UNESCO Associated Schools Network (ASPnet) are designated as the hubs to promote ESD. Out of 17 selected universities in East Asia worldwide, Nagaoka University of Technology (NUT) was appointed as the World-Hub University in 2018 by the United Nations. ESD implementation plan in Japan has adopted the concept of think globally and act locally to instill new attitudes and values in students with a vision to enable a more sustainable society (Japan National Commission for UNESCO, 2016). During the implementation of ESD in NUT, the need of more educational resources was observed, especially for teaching SDGs. Therefore, research for finding interactive educational resources was formulated.

Another prime goal of educational institutions particularly tertiary education platform like universities require to instill generic and social commitment skills to students for making them capable to solve real life problems at a local, regional, or international level (Forment, Caetano, Garcia-Penalvo, Amante & Martnez, 2015). Generic skills have become mandatory for the new generation workforce. For students, the opportunities to learn employability or generic skills hugely depend on teaching and learning environment of their universities (Lakkala & Ilomäki, 2015). Therefore, pedagogical approaches where learning outcomes are generated by the students' self-directed learning, feedback from the professor, well-designed tasks, effective team work and cooperation among students have become the upmost necessity (Garmendia, Aginako, Garikano & Solaberrieta, 2021). In this study, for product-based solutions, implementation of pedagogical approaches which manifest tangible innovations were thought necessary. Therefore, design-based learning (DBL) instructional approach was chosen. DBL is an integrated pedagogical insight of problem-based learning and design projects which also enhances generic skills of students through real-world engagement and cross-curricular challenges. Besides, DBL has been gaining popularity in most of the engineering institutions as practicing design is a fundamental process in engineering (Chandrasekaran, Stojcevski, Littlefair & Joordens, 2013; Gómez Puente, Van Eijck, & Jochems, 2013). DBL approach has been considered more beneficial in fostering students' sustainability competency compared to the lecture-based approach (Huang, Peng, Yang, Deng & He, 2020). This study first follows the steps of DBL approach to evaluate, conceptualize, develop, test and reflect for developing SDGs educational materials. Then, evaluates the impact of DBL on their generic skills development and finally reports the validity of proposed SDGs teaching resources or materials. The main objectives of this study are as follows;

- To describe the development of SDGs education resources i.e., games using DBL
- To check the generic skills of the students during DBL
- To evaluate and validate the effectiveness of the games as resource for teaching and learning SDGs

2. Methodology

Design thinking is a multidisciplinary approach and includes process of empathizing, defining, ideating, designing, testing, reflecting, and improving, all in line with problem solving through innovative products or ideas (Geitz & de Geus, 2019). For this study, four design processes proposed by Reeves (2006) was followed namely; analysis and problem framing; solution finding using existing designs, testing and refinement of solutions and reflection to improve designs.

2.1. Analysis and Problem Framing

In this first step, the initial needs of SDGs education were analyzed to identify what problems exist when SDGs teaching objectives are combined with learning design. The analysis team consisted of professors from NUT and technical colleges with 38 graduate students from different engineering departments. After literature review, it was evident that global concept like SDGs need resources which are simple to understand, easily reproducible, practical and widely available for different users. This data was then used to identify and define the problem for this study. As SDGs can be quite challenging to understand for different categories of people, especially younger group of people (elementary students to junior high school students aged between 7-17 yrs), the identified problem was to propose easy, fun and engaging method to teach SDGs to this category. To make sure that the students who are learning enjoys the process, all the activities were carried in both English and Japanese languages.

DBL workshops were conducted in group-based facilitation style. It started with the group formation and ice break. The students were asked to decide the roles such as facilitator, time keeper, writer and presenter. Each group consisted of 5-6 students. This step made sure that they develop good communication and teamwork competencies during any kind of activities. All students in each group were asked to present their game ideas to the other participating students. The best idea was chosen from each group based on the voting from the other teams. For this group work, Large Sized Handouts (LHS) were used to share the ideas. Each group assessed their game based on Plus Minus and Interesting analysis (PMI) and proposed the design of the games. LSH was prepared as proposed by Aburatani, Nakamura, Kuroda, Okada, Yamaguchi and Ichitsubo (2016) with a goal to "design a game and also directions to facilitate the students to set - up the games, how to play and its rules using PMI analysis.

2.2. Solution Finding Using Existing Designs

The second step is to solve problem identified in the first step. The design process began with the need of finding fun and exciting pedagogical approaches to teach SDGs. Given the fact that engineering institutions in Japan have huge number of youths, spreading information on SDGs through students from this institution is likely to be successful. The prospects of spreading knowledge on SDGs through engineering students is high. This is because engineering student have the qualities to find the possible solutions to any kinds of problem. In this step, design principles based on games were developed from the needs analysis and use of existing design principles from literature and the efforts from UNESCO which suggest that gamification can be an emerging trend of keeping the students engaged and motivated in the task (Darvasi, 2016). Games can be used to measure a very wide variety of tasks, as they are adaptable and easily standardized. Therefore, to develop exciting game, ideathons were conducted. On the day of ideathons, the students were introduced the concept and principles of SDGs. Also, the students were introduced with the theme, "transform the world". To make the rules for these games the students had to consider following points:

- Game goal - "How to solve world problems by SDGs".
- Target audience - Elementary students to high school students
- After playing these games, how will you determine whether your targets have understood about the theme or not?

At the end of the activity, survey questionnaire was given to the students for self and group assessment of their generic skills. The selection of seven generic skills such as accountability, communication, creativity, innovation, knowledge sharing, planning and organization and teamwork was based on the work by Kuroda, Danshita, Maki, Yamaguchi and Ichitsubo (2017) and Ichitsubo, Shigeyoshi, Kuroda, Yamada, Aburatani and Yamaguchi (2019). As the solutions, each team came up with different games and best three games were chosen based on the votes from the working groups. Ultimately, the chosen games were Bingo mat game (Bingo), Carrom board game and Sugoroku game (Japanese board game) as shown in Figure 1. The details and rules of these games are presented in the research works by Ichitsubo,

Yamaguchi, Fujii, Maharjan, Drier, Kuroda et al. (2019) and Maharjan, Kuroda, Okada, Nakamura, Aburatani, Yamaguchi et al. (2019).

Figure 1. Three games selected from the ideathon by the application of DBL (Ichitsubo, Yamaguchi et al., 2019)

2.3. Testing and Refinement of Solutions

The third step involved evaluating and testing the designed solution in a real world setup. During this step, the main purpose was to investigate the player's experiences of learning SDGs by involving in the games. Further, the purpose of this phase was to test the usability of prototypes developed. The idea behind testing these games over a period of two years with the students in real world was to check the level of excitement and enthusiasm with which players participated to play the games. The students demonstrated the games in science fair, exhibitions, local schools, colleges and conferences where the participants played games. Then, they were interviewed for the games they played.

2.4. Reflection to Improve Designs

This step provides the insights on the problems which could improve the game development. The researchers observed the players' reactions. After the gaming sessions, feedback was collected from the participants using questionnaires, regarding players' experiences, the ease of use and difficulties they faced before and after playing the games. Also, data was collected through vision sheets (the goal that they think can be achieved through their efforts) and opinion boards (the comment sheets for the improvement of games) after they finished playing the games.

2.5. Considerations for the Game Attributes

First, questionnaires and the responses relevant to game validations were noted. The team of teachers and students analyzed the players' data and questions carefully. Next, for evaluating the games and learning outcomes, 11 different attributes such as learning goal, content appropriateness, integration, extensibility, feedback, playability, competence, interaction, extensibility, challenge, efficiency, and cognitive motivation were considered. The questions were filtered from questionnaire and expressions that are closely related were categorized into different game attributes according to the game evaluation frameworks provided by Moizer, Lean, Dell'Aquila, Walsh, Keary, O'Byrne et al. (2019) and Al-Azawi, Ayesh and Al-Obaidy (2013). The attributes of the games are tabulated in Table 1 with their description and corresponding questions.

The study by Moizer et al. (2019) has briefly defined the above-mentioned attributes and categorized learning goal, content appropriateness, integration, extensibility and feedback under learning experience which describes the game effectiveness for goal achievability. Similarly, competence, playability, efficiency, interaction, cognition and motivation correspond to the game experience which describes the player's relationship with the game.

Attributes	Description	Surveyed questions
Learning goal	The goals and objectives of the game are clearly defined	Q1. Was this activity helpful for you to understand SDGs?
Content appropriateness	The purpose and rationale for the game on SDGs are fully explained	Q2. Do you think that the sustainable activities (actions) are important for achieving SDGs?
Integration	The games required to work in a team	Q3. Do you think is it important to work with others to achieve the SDGs ?
Extensibility	The game emphasized key points of SDGs and value as a learning resource	Q4. Can you always achieve 17 global issues?
Feedback	The game was effective in reviewing the material	Q5. Do you want to join this kind of activity in future?
Challenge	The experience was challenging	Q6. Were you able to find "Interesting facts about SDGs"?
Competence	The game was stimulating	Q7. Did you understand the "Relationship between your region and SDGs"?
Playability	The game items were appropriate	Q8. Was SDGs game enjoyable?
Efficiency	The directions were clear, concise, easily understood and effective use of time	Q9. Do you think in order to achieve the SDGs, it is always important to act on time or create awareness about SDGs?
Interaction	The game encouraged communicating with others and was fun	Q10. Was the conversation with students and group partners enjoyable?
Cognitive motivation	The game was thought provoking	Q11. Do you think regional issues are related to the SDGs (Global Issues)?

Table 1. Surveyed questions with description and considered attribute

2.6. Data Analysis

Principal component analysis (PCA) is one of the most commonly used methods of reducing the dimensionality of data sets. This method increases the interpretability of relationships between variable, while minimizing information loss. We performed PCA with the response dataset to evaluate if the surveyed samples were enough to check the correlation among attributes and validate the expected attributes of games as indicator of SDGs games as effective SDGs learning tool. The analysis was conducted using R programming language for the questions that corresponded well to the attributes considered. Correlation of the attributes were calculated and based on the correlation coefficient, we performed PCA on the response dataset with singular value decomposition of the centered (variables with mean = 0) and scaled (variables with standard deviation = 1) data matrix of the variables. Reliability test of Kaiser-Meyer Oklin (KMO) measure justified the use of PCA for response data sets.

3. Results

The results of this study are presented in two phases; Games development phase and Games demonstration phase.

3.1. Games Development Phase: Competences Developed in Students During the Solution Finding Step

The agreement of participants towards the level of generic skills improvement during self and group assessment was measured on the basis of Likert scale as shown in Figure 2. In self assessment, total 64 participants were involved (Sugoroku = 28; Carrom board = 26; Bingo = 10) and they assessed their peers and resulted in 295 responses in a group assessment and form a perception of DBL in the group (Sugoroku = 132; Carrom board = 116; Bingo = 47).

The assessments were carried out to study how DBL impacted in the development of their generic skills. Both self and group assessment results showed that the perception of students for each generic skill is skewed towards the positive end (neutral to strongly agree) for all three games administered. In self

assessment, more than 40 % participants accounted for the strong agreement towards generic skills development.

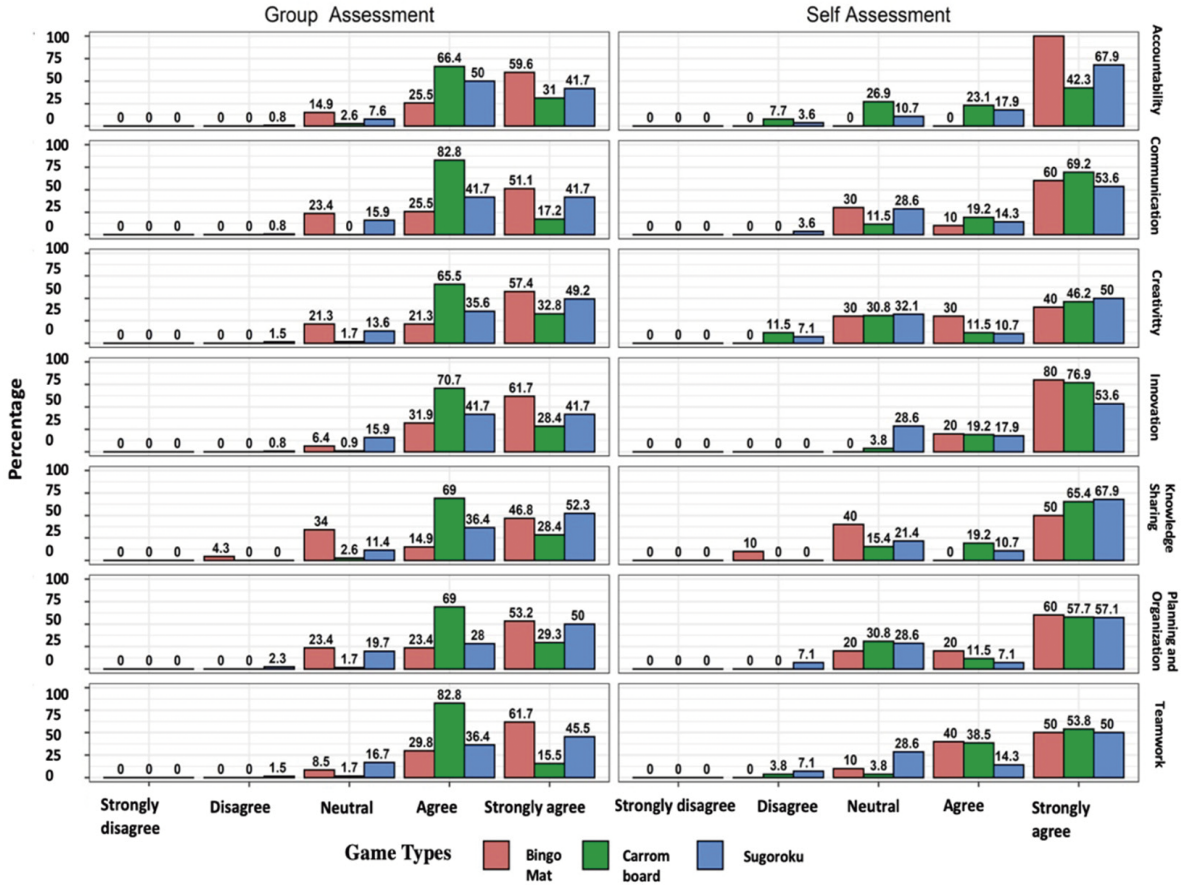

Figure 2. The agreements of participants towards the development of seven generic skills chosen in the solution development step. Attitude comparison between self assessment (N = 64) and group assessment (N = 295) for seven generic skills among three different games developed to teach SDGs (self assessment: Sugoroku = 28; Carrom board = 26; Bingo = 10 and group assessment: Sugoroku = 132; Carrom board = 116; Bingo = 47)

However, from group assessment of Sugoroku and Bingo games, more than 50 % students strongly agreed their generic skills improved while more than 60 % participants agreed their generic skills improved during Carrom board designing. Further, we performed a chi-square test to assess the agreement towards the level of skill development by types of games administered as shown in Table 2 for self and group assessment. It is more plausible to merge the responses of Likert scale to one category if the frequency of the responses is less than 5. Hence, for our Chi-square test, we merged the responses of strongly disagree and disagree to neutral since the frequency of responses for both were less than 5. Then after, we calculated the mean level of skill development perceived by participants from the Likert scale at the range of 5 (strongly agree), 4 (agree) and 3 (neutral/disagree) for both self and group assessment (see supplementary Table S1). Finally, we set our null hypothesis as agreement towards the level of skill development is independent to the type of games administered (i.e., Bingo, Sugoroku, and Carrom), different competencies (the skill sets: planning and organization, accountability, communication, creativity, knowledge sharing, teamwork, and innovation), and different measurements used (self assessment and group assessment). From the analyses, we found that the agreement level perceived in self-assessment showed no significant relation with the type of games administered for all competencies as indicated by high p-values (as high as 0.78; i.e., $p < 0.05$) except for innovation for which a nan value was observed resulting from a low frequency response from the participants towards neutral (disagree). However, in group assessment, the agreement level perceived for the generic skill development is strongly related to

the type of game administered and significant for all competencies as indicated by the low p-values (as low as 6.62 e^{-15}; i.e. $p > 0.05$) except for communication for which a non value was observed resulting from a low frequency responses towards neutral (disagree) for the games played.

Competencies	Mean level of skill development percieved by participants in Self Assessment					Mean level of skill development percieved by participants in Group Assessment				
	Sugoroku N=28	Carrom Board N=26	Bingo N=10	X^2	p value	Sugoroku N=132	Carrom Board N=116	Bingo N=47	X^2	p value
Planning and organization	3.56	3.76	4.00	1.72	0.78	4.04	4.7	3.940	57.85	8.25e-12
Accountability	3.94	3.70	4.00	4.21	0.38	4.41	4.6	4.057	25.38	4.21e-05
Communication	3.71	4.00	3.80	4.82	0.57	4.24	4.8	3.959	nan*	nan
Creativity	3.55	3.47	4.00	2.59	0.63	4.19	4.6	3.945	41.23	2.41e-08
Knowledge sharing	3.85	3.99	3.40	6.42	0.17	4.25	4.7	3.640	69.71	2.61e-14
Teamwork	3.62	4.20	4.10	7.92	0.09	4.17	4.8	4.172	72.53	6.62e-15
Innovation	3.83	4.13	4.20	nan	nan	4.24	4.7	4.217	42.61	1.39e-07

*nan: Not a number

Table 2. Assessment of competencies by type of games administered

3.2. Games Demonstration Phase: Results from Testing and Critical Reflection

3.2.1. Demographic Results of the Surveyed Respondents

The category and age of the participants during testing step is summarized in Table 3. Before playing the games, participants prior knowledge on SDGs was checked by asking if they have ever heard or known about SDGs. It was evident that the older people such as salary men, university and technical college students were already familiar with SDGs before playing the games. However, they seemed to lack the detail knowledge of these goals.

Participants	Age group	Yes (%)	No (%)
Technical College Students (n = 178)	15~20	68.54	32.58
University Students (n = 38)	20~27	73.69	26.31
Salary men (n = 15)	27 ~ above	66.67	33.33
Junior High School Students (n = 21)	12 ~15	23.25	76.75
Elementary Students (n = 43)	9 ~ 12	11.62	88.38

Table 3. Participants knowledge on SDGs

Of the total 295 test participants, technical college student comprised n= 178 (of which ~69 % have heard or knew about SDGs and ~31 % did not know about SDGs); university student comprised n= 38 (of which ~74 % knew or have heard about SDGs ad ~26 % have not heard about SDGs); salary men comprised n= 15 (of which ~67 % have heard about SDGs and ~33 % have not heard about SDGs); Junior high school comprised n= 2 (of which ~23 % have heard of SDGs and ~77 %; and Elementary students comprised n=43 (of which ~12 % knew about SDGS and ~88 % did not know about SDGS). We carried the test of independence to people category to check if the level of education affects on the knowledge of SDGs among the participants. As a result, there is a significant impact of education level on the knowledge of SDGs ($\chi^2 = 241.56$, df = 8, $p < 2.26 \times 10^{-16}$) which is also apparent from Figure 3.

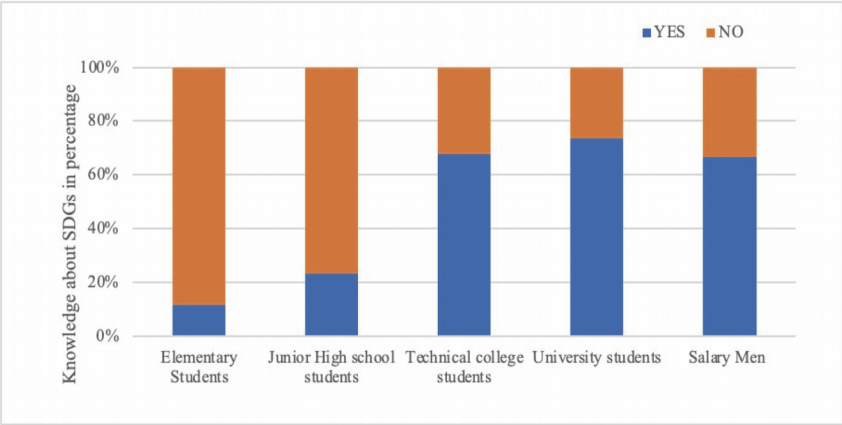

Figure 3. Participants knowledge on SDGs during survey

3.2.2. Attributes Validation of the Games

At 0.57, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was determined sufficient. Therefore, the sample size at n = 125 was satisfactory for PCA. Bartlett's test of sphericity X^2 = 168.91, df = 36, and p-value < 0.001, indicated that correlation (determinant of correlation = 0.245) between the variables (questions) was well defined for PCA. The contribution of variables (question) in PCSs is shown in Table 4. Eigenvalues set greater than 1 gave four principal components (PCs). Inspection of the scree plot and the data generated in parallel analysis confirmed that these four PCs explained 69 % of the variability in the original response dataset while components 5-9 totalled for 30 % variability (each contributing to less than 10 % in the response dataset), hence are disregarded as important components.

The first four PCs gave a mix of variables for the defined attributes (learning goal, feedback, integration, challenge, content, interaction, cognitive motivation, competence, and playability) (as shown in Table 1) for three different games. For explaining the variables (questions) rotation in only PC1 and PC2 space were considered and the result is presented in Figure 4. The bi-plot shows the relationship between all responses and portrays that Sugoroku and Bingo tend to fall more towards PC1 space whereas Carrom board towards PC2 space. Results indicate that the questions: Q1, Q4, Q8 and Q7 contributed more to the PC1 whereas Q5, Q3, Q9, Q2 and Q6 contributed more to PC2. The questions Q1, Q4, Q8 and Q7 were related to the attributes such as learning goal, feedback, interaction, and playability whereas Q5, Q3, Q9, Q2 and Q6 related to the attributes challenge, cognitive motivation, integration, content and competence (as indicated in Table 1).

Components	Eigenvalue	Variance %	Cumulative variance %
PC1	1.924	21.378	21.378
PC2	1.822	20.246	41.625
PC3	1.349	14.990	56.616
PC4	1.111	12.348	68.965
PC5	0.742	8.249	77.214
PC6	0.663	7.376	84.591
PC7	0.553	6.155	90.746
PC8	0.467	5.191	95.937
PC9	0.365	4.062	100

Table 4. Contribution of variables (questions) in the PCs

The supplemented bi-plot (Figure 4) illustrates the responses from the test participants. The participants who played Sugoroku and Bingo games indicated that the attributes such as learning goal, feedback, interaction, and playability were crucial for them to learn about SDGs. To investigate more details of these attributes, their dimensions were retraced in the literatures. It reflects that learning goal, feedback,

interaction, and playability corresponds to the learning experience dimension. On the other hand, the responses of the participants involved in Carrom board directed that challenge, cognition and motivation, integration, content, and competence were important attributes for them to learn about SDGs which corresponds to the gaming experience dimension. Therefore, PC1 signifies the learning experience whereas PC2 signifies the gaming experience. From these results, it can be observed that among the considered attributes, gaming experience and learning experience dimensions were valid for the games designed. Therefore, the effectiveness of SDGs games could be related to gaming and learning dimensions.

Similarly, the other two important PCs resulted into 27 % variability in the response dataset which were PC3 and PC4 as shown in Table 4 and supplementary Figure S1. It was observed that the PC3 is closely related with Q7, Q6, Q4 and Q5 which described the attributes like competence, challenge, extensibility and feedback that combinedly contribute to gaming and learning experiences. Whereas, PC4 is closely related with Q9, Q8 and Q3 which describes the attributes efficiency, playability, and integration that solely reflect the learning experience. The loadings of Q7 and Q6; Q4 and Q5; Q9 and Q8 in close proximity to each other indicate that attributes contributing to gaming experience dimension form separate cluster to attributes contributing to learning experience for PC3 and PC4.

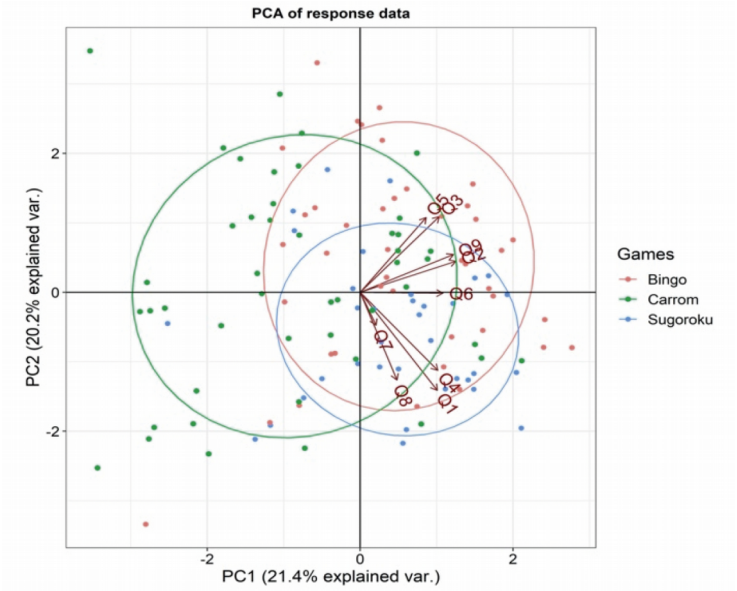

Figure 4. A bi-plot showing placement of responses from the participants as per the PCA components with respect to different questions after playing the games. Space components close to each other share similar responses.

4. Discussion

The goal of this study was to describe the process of SDGs games development using DBL approach and its effect on the generic skills of the students. We also explored the relationship between the attributes of the games and checked which attributes contributed to the effectiveness of the games.

4.1. DBL Experience and Competencies Acquired by the Students

In this study, we implemented the steps of DBL to develop games for teaching SDGs. The steps of DBL were followed from defining the problem to finding the solution in the form of prototypes. Unlike other conventional classroom set up, DBL emphasized on process along with the content creating a stimulating environment that promoted student centered learning. Learning in this manner became more exciting and purposeful with ideas being converted into tangible forms. Through this process, the students'

transformed their ideas through visualization and applied the information to find the fun and easier way to teach SDGs through games. The survey questions helped the students to choose their targets users and demonstrated a team effort to come up with ideas that teach importance of SDGs. The feedback of the players also helped them to reconsider their ideas and improve their prototypes as well as strong collaboration between teacher-student was observed which is usually absent in conventional classroom. The observation of research agrees with the argument presented by Ichinose (2017) that Japanese education system needs to develop more teacher-student focused learning environment and henceforth DBL could possible fulfill that gap.

Moreover, in each step, DBL had a positive effect on the improvement of the generic skills of the students. The results are in accordance with the research by Koivisto, Haavisto, Niemi, Haho, Nylund and Multisilta (2018) that DBL enhances the learning of engineering students to acquire basic competencies and help them to become active participants in solving everyday engineering problems. Group assessment showed that their perception of generic skill improvement was influenced by the type of the solution or game they developed. However, during self-assessment, they considered the competencies were equally improved irrespective of the game types. This could be explained by the students' familiarity with these games. The researches led by Kuramoto (2002) and Atake (2003) reported the wide use of common games like Bingo and Sugoroku to teach English languages in junior and high schools. Unlike these two games, Carrom board game is not a popular game and many of the students didn't know about it. This might have induced strong teamwork and communication skills (82.8 %) to find more information about it and conceptualize to prototype resulting in slightly different perception towards self and group assessment. The positive inclination towards development of generic skills suggest that DBL should be included in education curriculum (Chandrasekaran et al., 2013; Huang, Tlili, Yang, Chang, Wang & Zhuang et al. (2020).

Our study is also in line with the suggestions presented by Geitz & de Geus (2019) that DBL could also be considered as sustainable learning environment for finding solutions to social problems. The survey results depicted that still younger students are unaware about SDGs which in itself is a big social problem. Hence, it is necessary to put emphasis on the education of SDGs targeting younger age group too. The other advantage of teaching them at the early age is related with their capability to grasp the concept and reflect it to their behavior and attitudes for the rest of their lives (Kahane, 2018). Further, in a recent study, researchers revealed that young engineers as future leaders represent catalysts for change and can challenge the status quo to achieve the SDGs through ESD by 2030 (Bonsu, Tyreehageman & Kele, 2020). It is therefore, important for students to have learning environment from younger age to see the world with a new vision and prepare to adopt new ways of working and thinking about the impacts of the present activities into the future. With less than a decade left to take actions to deliver SDGs, an approach made in this study could also help to make significant impacts in the perception of people and inspire them to ponder about the issues around them.

4.2. Effectiveness of Games for Teaching SDGs

The efforts for achieving SDGs by 2030 reinforces the need of developing SDGs educational resources in time. Till this date, there are limited studies on the approaches of ESD (Kozak, 2020). This study proposes games as a resource for providing education on SDGs as an attempt under ESD. We evaluated and validated the game attributes quantitatively by using PCA. The results confirmed that that not all attributes equally contribute to effective learning which was true for other conventional games types. The results revealed that the game could be more effective in teaching SDGs among participants when the purpose and rationale of the games are clearly defined (Q2), when the game is though provoking (Q12); more stimulating (Q7); require team work (Q3), and reflects and review in the goals and objectives and topics (Q5). The game being enjoyable (Playability) and competent does not necessarily account for effective learning of SDGs. On contrary, working together (integration) to find interesting facts about the topics (challenge) to solve regional problems (cognitive motivation) are important in broadening the knowledge of SDGs among the learners.

Furthermore, when comparing three games from players perception, the results highlighted that Carrom board is more feasible for gaming experience while Bingo and Sugoroku is for learning experience. The other factor is familiarity with the games as Carrom board was a new game with more challenges whereas Bingo and Sugoroku were well known games which were comparatively easier to design. Nonetheless, it is assumed that these games have a positive impact on peoples' understanding of SDGs. Also, each game is designed to be played in a group which stimulated engagement as well as exchange of information about SDGs and generated awareness among people. From the observation, we could arguably say that games could be suitable approach to promote understanding of SDGs for ESD.

Despite the positive results, application of SDGs games may have few challenges. Firstly, the interest of the students on games may have moderating effect on its effectiveness. For example, inactive students resulting in a low level of learning and not enjoying the games. Secondly, the feasibility of playing these games is significantly affected by the availability of instructors. It could be challenging to organize enough teachers in institutions who could actively teach the students.

It is also noted that this study is focused on the engineering institutions and does not explore the effects of the DBL approach on the competencies of students belonging to other educational fields. The inferences of the activity would have been different if the students from other educational backgrounds were involved. Therefore, the practicability of this learning approach to different domain of education cannot be confirmed without conducting more researches on this topic. There were limited generic skills considered in this study specific to the engineering students. Therefore, considering the 21st competencies or sustainability skills would provide more insights of the other competencies which could have been enhanced through this learning method. Furthermore, the SDGs games were demonstrated in only three events with limited number of individuals and its playability with wide range of age groups have not been investigated well. In the future, we hope to test these games in different platforms with wider range of players. In addition, more research would be carried out to use ICT tools to digitize these games. Since the mode of education is transitioning to online platforms due to prevailing pandemic, it would be interesting to explore these games through digitization.

5. Conclusions

In this paper, we employed DBL to propose the approach for teaching SDGs to the people. In DBL environment, the overall experience of the students was positive. Also, this study emphazied on the application of DBL in the education curriculum particularly in engineering institutions to foster generic skills of students as well as teacher student interaction. The output of DBL was three interesting games namely Bingo, Carrom board and Sugoroku designed by the students as SDGs games. During self assessment, students enhanced their generic skills in DBL irrespective of the type of the games they designed. While in the group assessment, their level of perception was significantly related to the game types. Game development results indicated that the design of carrom game required stronger teamwork and communication skills than Bingo and Sugoroku due to its newness to the students. These games were tested for its efficiency as a resource to teach and learn about SDGs. The results showed that SDGs games could be considered effective in terms of learning and gaming experiences. The findings of this study also highlighted the fact that SDGs must be taught from the younger age as the level of education had significantly impacted on their knowledge about SDGs to promote ESD in educational sector. This study showed how design specific games can help people of different categories to understand SDGs through simplified and easier approach like SDGs games and could be considered as SDGs teaching and learning resources for educators. Thus, integrating DBL and SDGs for ESD hold much value for educators to design invigorating study experiences for the learners as well as teachers to challenge the world issues.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix

Cross Frequency Table of Self Assessment for Design Based Learning															
	Sugoroku (n = 28) 5 → 1					Carrom(n =26) 5 → 1					Bingo(n = 10) 5 → 1				
Develop generic skills	SA	A	N	DA	SDA	SA	A	N	DA	SDA	SA	A	N	D	SDA
Planning and organizing	2	16	8	2	0	3	15	8	0	0	2	6	2	0	0
Accountability	5	19	3	1	0	6	11	7	2	0	0	10	0	0	0
Communication	4	15	8	1	0	5	18	3	0	0	1	6	3	0	0
Creativity	3	14	9	2	0	3	12	8	3	0	3	4	3	0	0
Knowledge sharing	3	19	6	0	0	5	17	4	0	0	0	5	4	1	0
Teamwork	4	14	8	2	0	10	14	1	1	0	4	5	1	0	0
Innovation	5	15	8	0	0	5	20	1	0	0	2	8	0	0	0

Cross Frequency Table of Group Assessment for Design Based Learning															
	Sugoroku (n = 132) 5 → 1					Carrom(n = 116) 5 → 1					Bingo(n = 47) 5 → 1				
Develop generic skills	SA	A	N	DA	SDA	SA	A	N	DA	SDA	SA	A	N	D	SDA
Planning and organizing	2	16	8	2	0	80	34	2	0	0	11	25	11	0	0
Accountability	5	19	3	1	0	77	36	3	0	0	12	28	7	0	0
Communication	4	15	8	1	0	96	20	0	0	0	12	24	11	0	0
Creativity	3	14	9	2	0	76	38	2	0	0	10	27	10	0	0
Knowledge sharing	3	19	6	0	0	80	33	3	0	0	7	22	16	2	0
Teamwork	4	14	8	2	0	96	18	2	0	0	14	29	4	0	0
Innovation	5	15	8	0	0	82	33	1	0	0	15	29	3	0	0

Table S1: Total responses from the participants for development of generic skill while playing board games to learn SDGs

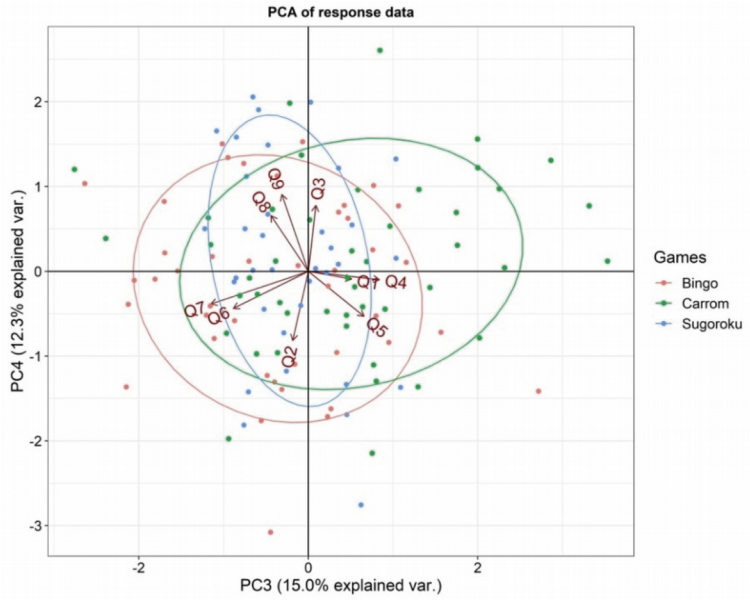

Figure S1. A bi-plot showing placement of responses from the participants as per the PCA components (PC3 and PC4, the other two PCs that results into 27 % variability in the participants response dataset) with respect to different questions after playing the games. Space components close to each other share similar responses.

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