Heliyon 9 (2023) e20420

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Effectiveness of gamification and selection of appropriate teaching methods of creativity: Students' perspectives

Kuo-Wei Lee

Center for the Liberal Arts, College of General Education, National Kaohsiung University of Science and Technology, Taiwan

ARTICLE INFO

Keywords:
Effective teaching
Analytical hierarchy process
Mandala thinking
Enhance learning
Teaching strategies
Student self-assessment

ABSTRACT

Complex creativity and multiple learning objectives often require combining several teaching methods, and gamification may be an effective teaching strategy for enhancing learning. However, few studies have examined the combined effects of implementing gamification and multiple teaching methods in a course from students' perspectives. Therefore, this study implemented gamification and six teaching methods of enhancing college students' creativity in university creativity and innovation course in November and December 2021 and aimed to examine the effects on their creativity, collaboration, and communication skills and used the Analytical Hierarchy Process to identify more effective teaching methods corresponding to the learning objectives from students' perspectives. The results showed that students perceive that gamification could stimulate their motivation, attitudes, and interest in learning and enhance their creativity, collaboration, and communication skills. Furthermore, Mandala thinking was the most effective teaching method for the overall goal. In contrast, the most effective teaching methods for the creativity, collaboration, and communication skills learning objectives were the SCAMPER technique, balloon competition, and Mandala thinking, respectively. The results provide essential references for selecting effective teaching methods that meet the teaching objectives.

1. Introduction

Fostering student creativity in higher education is necessary. Creativity is defined as a product or idea that is novel (or original, unique, or unusual) and useful (or has value, or fit, or is appropriate) [1,2]. Creativity has been considered one of the crucial competencies in the 21st century [3–5] and is also essential for innovation and entrepreneurship [6–9]. Creativity can and should be taught in higher education [10–14]. Different creativity teaching methods affect the effectiveness of enhancing creativity [15]. Several studies have attempted to enhance the creativity of college students [16,17]; however, the evidence for the impact of various teaching methods on student creativity is inconclusive [18]. We need more empirical research to understand how to enhance the creativity of college students and find appropriate teaching methods.

Gamification may be an effective teaching strategy for enhancing creativity [19–22]. Teaching creativity is a complex, elusive, and multifaceted process [23,24]; therefore, activities that interest students need to be designed to help teach creativity [25]. Some studies have used joy and fun gamification to enhance students' creativity [26–29]. In addition, Parjanen and Hyypiä [30] found that gamification could promote individual and collective creativity. Taesotikul [31] confirmed that gamification could improve students' creative problem-solving skills. However, in recent years, most research has used gamification in online learning, while the gamification of face-to-face courses requires more research [32,33].

E-mail address: guowei@nkust.edu.tw.

https://doi.org/10.1016/j.heliyon.2023.e20420
Received 7 May 2023; Received in revised form 9 September 2023; Accepted 25 September 2023
Available online 26 September 2023

Complex creativity and multiple learning objectives often require combining several teaching methods [34]. However, most studies that aim to enhance creativity use only a single pedagogy [17,35–38]. Few studies have examined the combined effects of various pedagogies on creativity [38]. Moreover, little is known about the impact or relationship between using multiple teaching methods in gamification on creativity, collaboration, and communication skills.

Therefore, this study implemented gamification and six teaching methods to enhance creativity, including divergent thinking, balloon competition, the method of focal objects, forced relationships, the SCAMPER technique, and Mandala thinking in a university creativity and innovation course and aimed to examine the effects on students' creativity, collaboration, and communication skills and to use the analytical hierarchy process (AHP) to identify more effective teaching methods corresponding to the learning objectives from students' perspectives. The meaning of creativity in this study is the ability of students to come up with novel and useful ideas or products. The study focused on answering the following questions: (1) What is the impact of combining six teaching methods with gamification on college students' creativity, collaboration, and communication skills? (2) What are the most effective teaching methods for students regarding various learning objectives?

2. Literature review

2.1. Teaching creativity

Numerous studies have shown that creativity can be enhanced through various teaching methods; however, not all findings are positive and efficacious. Positive and effective findings, such as those by Xu and Hamari [39], found that gamification significantly increased people's creativity compared to money and punishment. Lee and Portillo [40] implemented a one-semester creativity course with results that positively impacted students' domain-specific creativity. Lee (2020) found that the creative personal identity of first-year college students was significantly improved after taking an interdisciplinary creativity course. In addition, Susetyarini [41] used a problem-based learning approach, Rahardjanto [42] used Hybrid-PjBL, and STEM and STEAM education researched by Aguilera and Ortiz-Revilla [43] all had a significant positive impact on enhancing creativity.

In contrast, negative and invalid findings, such as those by Duncan [44], used Breakout EDU to develop students' creativity; however, the results showed no significant difference. Liu [45] used interdisciplinary teaching to promote nursing students' creativity and showed no significant difference in effectiveness for typical nursing students. Huang [16] showed that the effectiveness of fostering creativity through university courses shows ambiguous results. Further empirical research is needed.

There are no apparent conclusions or consensus about teaching creativity, and how better to teach it concerns many teachers. Fostering creativity is a complex process [46,47]. Teachers focus on fostering student creativity, but there may not be an easy or straightforward answer for schools and teachers [48,49]. Technology in teaching creativity should be novel, fun, and valuable; however, even after teaching a creativity class for over two decades, as Simonton [50] has done, he still falls short of that goal.

Teaching creativity continues to face many challenges, and further research is needed on effective teaching strategies to enhance instruction. Students perceive that appropriate teaching methods could significantly promote creativity [51]. However, teachers generally teach creativity according to the circumstances they consider appropriate [52,53] and face various challenges [54]. Due to various factors, teaching methods that enhance creativity may be effective in one course and ineffective in another [55,56]. Teaching creativity is sometimes confused with creative teaching [57,58]. Teachers and students may have different conceptions of creativity [59–61], and learning outcomes can vary depending on the subject and student audience [62–65]. Generic teaching techniques that foster creativity may not be as appropriate for all domains [66], and teachers need more references to help select the appropriate teaching methods [67]. Therefore, this study will attempt to identify teaching strategies that can effectively enhance the creativity of college students.

2.2. Teaching methods on creativity

This study implemented six teaching methods to enhance creativity, briefly described below: divergent thinking, balloon competition, the method of focal objects (MFO), forced relationships, the SCAMPER technique, and Mandala thinking.

Divergent thinking, which represents a significant component of creativity [68,69], symbolizes a style of thinking that allows for generating many ideas [70]. In alternative use tasks (AUT) [68], widely used to assess divergent thinking, people are asked to generate as many original uses as possible for an object (such as a pen or paper clip) [71,72].

The balloon competition is a self-designed teaching for this study, taking the balloon chair that can be sat on as an example to stimulate students' creative thinking. Teams must work with limited time and materials to create a balloon structure that can bear a specific load. As Wujec [73] noted, the marshmallow challenge is a creative teamwork task that can stimulate students' creativity [74,75].

MFO is a method for enhancing imagination, association, and creative thinking [76]. It involves taking the innovative object as the focal object and then randomly selecting another completely unrelated object, and using various seemingly mismatched features of that random object to freely associate with the focal object, thereby generating creative ideas [77,78]. Finally, an unusual and fruitful combination is chosen to refine the focal object. In addition, the forced relationship method is similar to MFO but does not use the focal object. This technique generates creative ideas by randomly associating features of two unrelated objects [79].

The SCAMPER technique has proven to be a method to stimulate creative thinking [80,81]. Each letter of SCAMPER represents a different method to generate new ideas. These methods are substitute, combine, adapt, modify, put to another use, eliminate, and rearrange [82]. Students can generate many innovations using only one or more methods [83].

Mandala thinking, also known as the Mandala chart [84] or the nine-square Mandala [38], is a popular method to enhance creativity. Students can generate ideas by first writing down the topic to be ideated in the central grid of the nine-square grid chart and then filling in the other eight surrounding spaces with related ideas. In addition, Chang [38] also indicated that Mandala thinking is more efficient in stimulating new and unique ideas for Taiwanese students.

2.3. Gamification

Gamification may be an effective teaching strategy to enhance learning, and its impact on learning is intriguing. Gamification is defined as "the use of game design elements in nongame contexts" [85], in which game design elements contain goals, points, badges, feedback, levels, challenges, competition, rewards, fun failure, etc. [86–88]. Gamification has only been widely used since 2010 [89]. Research on "gamification in education" is still in the developmental stage [90]. More empirical evidence is needed regarding the impact of gamification on student learning.

Numerous empirical studies have attempted to confirm whether gamification contributes to learning. The favorable results have raised expectations for the development of gamification in education. Several studies have shown that gamification could increase student motivation, emotional engagement, or enjoyment [21,91–94]. It is also beneficial to enhance creativity and idea generation; for example, Skaržauskienė and Kalinauskas [95] showed that gamification might foster collective creativity since it increases the enjoyment of engagement in activities. Marasco [96] found that gamification was a positive method to engage and motivate college students and to introduce creativity and innovation into design education.

The development of gamification in education is promising; however, not everything works well [97]. For many reasons, the theory does not always translate into practical outcomes [17]. There have been mixed results from gamification studies [86,98,99]. Mårell-Olsson [100] used gamification to develop students' 21st century skills but found it complex. Some research has indicated that gamification in education may not produce the expected results and may even have adverse effects. For example, Kwon and Özpolat [101] implemented gamification in an undergraduate course and found that it significantly decreased content knowledge, satisfaction, and course experience. Hanus and Fox [102] found that gamification harms students' final exam scores and motivation. Almeida [103] systematically mapped the negative effects of gamification in education, resulting in 77 papers reporting the adverse effects of game design elements. There is insufficient evidence to support that the effect of gamification on creativity is positive [104]. Therefore, this study aimed to find more empirical evidence of the impact of implementing multiple teaching methods in gamification on students' creativity, collaboration, and communication skills from college students' perspectives.

2.4. Analytic hierarchy process (AHP)

AHP is a multicriteria decision-making method developed by LT Saaty in 1971 and is widely applied in decision-related applications [105,106]. It is often used to rank attributes, which relies on pairwise comparisons of experts to derive priorities [107].

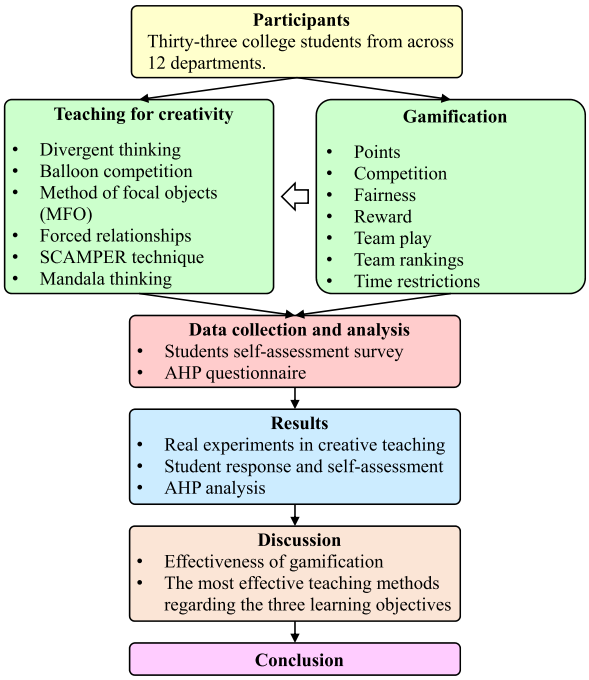


Fig. 1. Flow chart of the study procedure.

Applications of AHP in teaching include identifying appropriate mathematics teaching methods [108], assessing learning or teaching quality factors and systems [109,110], selecting appropriate teaching tools [111] or engineering education software [112], and ranking factors that influence effective teaching [113].

AHP is a simple and efficient decision-making method well-suited for student use. Raadabadi [113] employed the AHP to prioritize the factors influencing effective teaching from medical students' perspectives. Kim [114] examined the differences between industry practitioners and students in perceiving the core competencies of tourism graduates employing the AHP methodology. Huang [115] designed an evaluation method for ubiquitous learning by applying an AHP questionnaire to students.

3. Materials and methods

This study, conducted in November and December 2021, aims to examine the effect of combining six teaching methods with gamification to enhance college students' creativity in a creativity and innovation course. The study procedure consisted of several stages, as illustrated in Fig. 1.

First, thirty-three college students from across 12 departments participated in this study. The chosen teaching methods (divergent thinking, balloon competition, the method of focal objects, forced relationships, the SCAMPER technique, and Mandala thinking) were selected for their potential to enhance creativity and align with the course goals. Next, gamification was incorporated, and participants were informed about the course structure before teaching. Each teaching method was implemented for 2 h per week over six weeks. And then, data was collected after the creativity teaching. The research instruments included a student self-assessment survey and an AHP questionnaire. The self-assessment survey measured students' perceptions of their creativity, collaboration, and communication skills. At the same time, the AHP questionnaire was employed to identify teaching methods deemed more effective by students in achieving the desired learning objectives. The collected data was analyzed, followed by a discussion and conclusion.

3.1. Participants

Thirty-three undergraduate students from the National University of Science and Technology in Taiwan participated in this study, which adhered to rigorous research ethics guidelines. The study was approved by the National Kaohsiung University of Science and Technology under number NKUST-1101035, and informed consent was obtained from all participants. Students who participated in this study were voluntary. They were fully informed of the study's purpose and procedures and received no compensation for their involvement. The study did not harm the participants, and measures were taken to ensure their confidentiality and privacy throughout the study. Two of these 33 participants did not complete the questionnaire and were thus excluded from data analysis. Therefore, the final data analyzed came from the remaining 31 students (15 males and 16 females; ages 19–22 years, M = 20.26 years) who participated in the entire study and completed the survey while they were enrolled in the College of Foreign Languages (39%), College of Business (39%) and College of Engineering (22%).

3.2. Teaching for creativity

The main teaching goal set for this study was to combine six teaching methods with gamification to enhance students' creativity, communication, and collaboration skills, all of which are critical skills for the 21st century [116]. The meaning of creativity in this study is the ability of students to come up with novel and useful ideas or products. Upon completing the program, students will have acquired critical skills. Facing user needs and future real-world challenges, students can use their creativity, collaboration, and communication skills to generate novel and useful ideas or products. For example, students will have the skills to create a multi-functional creative pen with display time, multiple colors, and erasable functions to meet student exam needs; invent a helmet that incorporates positioning and cooling mechanisms to improve comfort and safety at work; design a water purification device that provides clean drinking water; devise products made from recycled waste to reduce environmental impact and develop a mobile app that integrates wearable device and essential oils to improve sleep quality.

The teaching procedures for fostering creativity are shown in Table 1. Gamification and teaching methods were introduced in week 1. Most students in the course did not know each other at the beginning and were divided into heterogeneous groups of 4 or 5 people. Subsequently, the six teaching methods for creativity combined with gamification were implemented from weeks 2–7. Finally, week 8 was the presentation of results, awards, and questionnaires.

Table 1
Teaching procedures for fostering creativity.

Week	Course content
Week 1	Grouping, introducing gamification and teaching methods
Week 2	Divergent thinking teaching
Week 3	Self-designed balloon competition
Week 4	Method of focal objects
Week 5	Forced relationships
Week 6	SCAMPER technique
Week 7	Mandala thinking
Week 8	Presentation, awards, and questionnaires

For a total of 6 weeks of continuous gamified creativity teaching, including divergent thinking, self-designed balloon competition, method of focal objects (MFO), forced relationships, SCAMPER technique, and Mandala thinking, the sequence and content of implementation were as follows.

The first was to implement divergent thinking teaching. During the divergent thinking process, the first was "Uses of a Pen," and the second was "Uses of Plastic Cups." Each team wrote their ideas on sticky notes; each development took approximately 30 min. The team that found the most versatility won.

The second implementation was balloon competition. Teams had 30 min to work together to create a balloon structure that could hold the weight of a bottle of water (approximately 600 g). Each team had two circles and 20 long balloons for the first round of competition. If the balloon broke, it was not replaced. Only balloons can be used, not other materials. In the second round, materials were added based on the results of the first round (last place adds the most), and the material exchange was open to keep the competition going. The balloon with the highest weight-bearing height (distance from the highest horizontal point to the table) won.

The third implementation was MFO teaching. Teams freely selected the focal object and randomly chose at least five unrelated objects as the medium for the free relationship of new ideas. The team discussed and evaluated all new ideas and chose two to sketch. Finally, the whole class voted online, each person could vote up to three times, and the group with the most votes won.

> The fourth implementation was forced relationships teaching, similar to MFO. The team freely chose two unrelated things and used the teammates' imagination to find as many new ideas as possible. After the team discussed and evaluated, two ideas were selected for sketching, the class voted, and the one with the most votes won.

The fifth implementation was the SCAMPER method. Each team used the worksheet designed in this study to generate as many ideas as possible. In approximately 60 min, by following the steps of each alphabet of SCAMPER. There were two parts to earn points: the team that found the most creative ideas and the idea that received the most votes after a class-wide vote.

The final implementation of the course was Mandala thinking. Each team used a worksheet with a nine-square grid designed for this study, wrote down the theme to be developed on the center grid of the worksheet, and then used the other eight surrounding grids to generate creative ideas. Similarly, the team evaluated and selected two ideas for sketching, then the class voted, and the one with the most votes won.

3.3. Gamification mechanisms

Considering the learning environments [117] and teaching factors [88,118,119] in gamification, the gamification mechanism in this study was designed as follows:

- Simulation of team competition.
- Team practice time is approximately the same for each teaching method (approximately 60 min total).
- The maximum points earned and the point intervals were the same each week to maintain fairness and competition. The team that won first place received 14 points; the second place received 12 points, etc.
- The competition points for each team were announced weekly.
- Creativity teaching implementation results and gamification points were calculated and confirmed by the students.
- The reward for the competition is a red envelope with cash.

3.4. Research instrument

The main research instruments in this study were a student self-assessment survey and the AHP method. These two instruments are described below.

3.4.1. 3.4.1 Self-assessment survey

This study used a self-assessment survey, as in Appendix 1, to allow students to self-assess their creativity, collaboration, communication skills, and perceptions of gamification. In week 8, after the creativity instruction, a student self-assessment survey was administered. A 7-point Likert scale was used for all survey items, and participants rated each item from 1 (strongly disagree) to 7 (strongly agree), with scores calculated as the mean of all items.

3.4.2. 3.4.2 The AHP method

Based on various strengths, AHP was selected as the research method in this study. The selection of appropriate teaching methods is an essential factor in education. Teachers should consider teaching objectives, classroom conditions, and student situations in teaching methods. Sometimes it is necessary to combine multiple teaching models to respond to different teaching sites [120]. One possible and feasible approach to comparing and selecting teaching methods is the AHP [111]. The AHP method is a well-established and widely used decision-making tool that enables the systematic and structured evaluation of complex topics. When applied to multicriteria decision-making problems, AHP can transform psychological attributes into mathematical reasoning through hierarchical structures [121]. AHP is also a quantifiable approach and allows our study to determine each alternative's relative weightage, ensuring a fair comparison at each level. Additionally, the AHP is a relatively simple and quick decision-making method suitable for students to fill out. Therefore, this study used AHP as a research method to identify more effective teaching methods corresponding to the learning objectives from students' perspectives.

As shown in Fig. 2, we used a typical top-down three-level AHP framework [122]. The first level's goal was to "Identify more effective teaching methods corresponding to the learning objectives." The second level included three objectives: creativity, communication, and collaboration skills. The third level was six alternatives, namely, six teaching methods, including divergent thinking, balloon competition, method of focal objects, forced relationships, SCAMPER technique, and Mandala thinking. Additionally, this study used an AHP questionnaire with a 1–9 scale, where 1 is equal importance, 3 is moderate importance, 5 is essential or strong importance, 7 is very strong importance, 9 is extreme importance, and 2, 4, 6, and 8 are intermediate values between the two adjacent judgments [107,123]. The AHP questionnaire, as in Appendix 2, was also administered in week 8.

3.5. Data collection and analysis

All students taking the Creativity and Innovation course were invited to complete the self-assessment and AHP questionnaire at week 8. Before analyzing the data, we calculated Cronbach's alpha using IBM SPSS Statistics 26 software to determine whether the internal reliability of the measurements was consistent. The Cronbach's alpha coefficient for the student self-assessment survey was 0.973 (0.7 or more is acceptable), indicating good consistency in internal reliability. And then, a narrative statistical analysis was conducted using SPSS statistical software.

In addition, after students completed the AHP questionnaire, this study applied Excel software to analyze the data of pairwise comparisons, mainly including priority analysis and consistency verification. The calculated weights and priorities of the six teaching methods regarding the learning objectives were based on the results obtained from the students' paired comparisons. The data were analyzed with the following steps:

1. Build the pairwise comparison matrix.
2. Calculate the weights and priorities for each hierarchical element.
3. The consistency of the AHP analysis results was analyzed and checked by calculating the consistency index (CI), consistency ratio (CR), and random consistency index (RI).

If the value of the CR (CR=(CI)/(RI)) is no higher than 0.1, then the consistency of the matrix is acceptable.

4. Results

4.1. Real experiments in creative teaching

4.1.1. Divergent thinking

Teams come up with significantly more uses than in the past when there was no competition. With the same amount of time and number of people, most teams only came up with approximately 30–40 uses in the past. In contrast, the first-place team came up with 63 uses in the first round of "Uses of a pen (Fig. 3a)." Moreover, the first-place team also came up with 62 uses in the second round of "Uses of a plastic cup (Fig. 3b)."

4.1.2. Balloon competition

The balloon weight-bearing height competition atmosphere was challenging, exciting, and joyful (Fig. 4). The results showed that the first-place was 89 cm (Group 7), and the second place was 70 cm (Group 1). The third place was 65 cm (Group 2), which was also higher than when there was no competition.

4.1.3. Method of focal objects and forced relationships

MFO and forced relationships are similar methods, so the results are presented together. After associative thinking, each team chooses two ideas for the competition. One of the voting results was the "Portable Internet Desk" (Group 1), and the second place was the "Rechargeable Pencil Case" (Group 7) (Fig. 5).

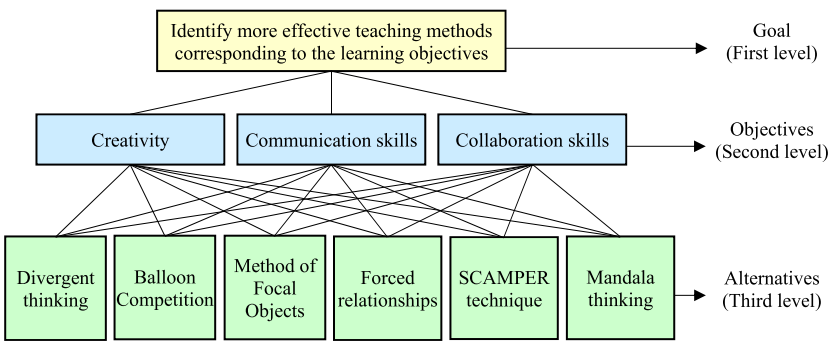


Fig. 2. Hierarchy framework of AHP for the selection of teaching methods.

(a) (b)

Fig. 3. Results of two rounds of divergent thinking implementation: (a) Uses of a pen and (b) Uses of a plastic cup.

Fig. 4. Results of balloon competition.

4.1.4. SCAMPER technique

Each team used the SCAMPER worksheet (Fig. 6) to generate as many ideas as possible. The team that came up with the most ideas had 28 ideas, and the top idea in the voting was "ballpoint pens with correction tape."

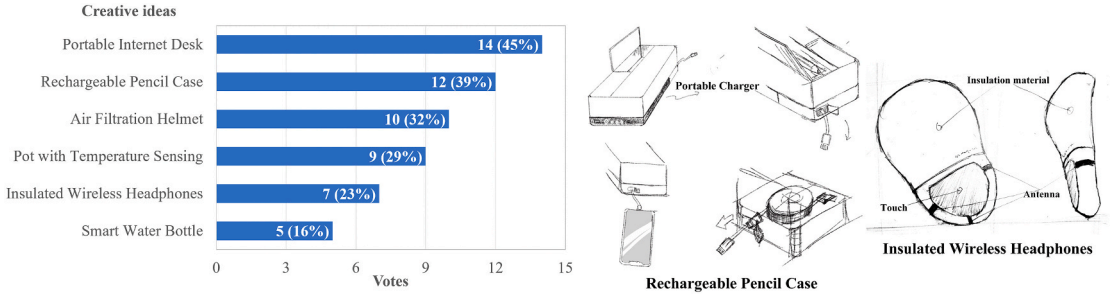


Fig. 5. Online voting for creative ideas.

4.1.5. Mandala thinking

Each team used the nine-square grid worksheet (Fig. 7a) to generate creative ideas and selected two ideas for sketching. There are two first places in the voting results: the "projectable ring" and "automatic temperature control thermos (Fig. 7b)."

4.1.6. Gamification rewards

The reward for the competition was a red envelope with cash. The number of gamification points earned by each team per week is shown in Fig. 8a, and finally, team 6 won first place and a cash reward of approximately $15 (Fig. 8b).

4.2. Student response and self-assessment results

The students rated the results of applying gamification in the Creativity and Innovation course highly and positively. They perceived that gamification could enhance their creativity, collaboration, and communication skills while stimulating their learning motivation and interests. As shown in Table 2, the student's self-assessment results showed that the mean score for all questions exceeded 5.2. Students preferred gamification to traditional lectures. In addition, students also perceive that gamification could stimulate their motivation, attitudes, and interest in learning and enhance their creativity, collaboration, and communication skills. Gamification can enhance the learning outcomes of Creative and Innovative courses. The students' responses and self-assessment results were positive.

Additionally, the student responses are listed below.

- "*The course is extraordinary. It could stimulate imagination, and the games were fun.*"
- "*I think gamification can make me want to learn more, and it would also deepen the relationship between team members and increase communication skills through the game.*"
- "*This course is beneficial and made us develop many creative ideas.*"
- "*I think the class is very delightful.*"
- "*All I can say is that the course is so much fun and taught us to do more with our brains and become more imaginative.*"
- "*The course content is quite interesting, although I often had to rack my brains to develop many new ideas. It is good to extend gamification to learn to other general courses.*"

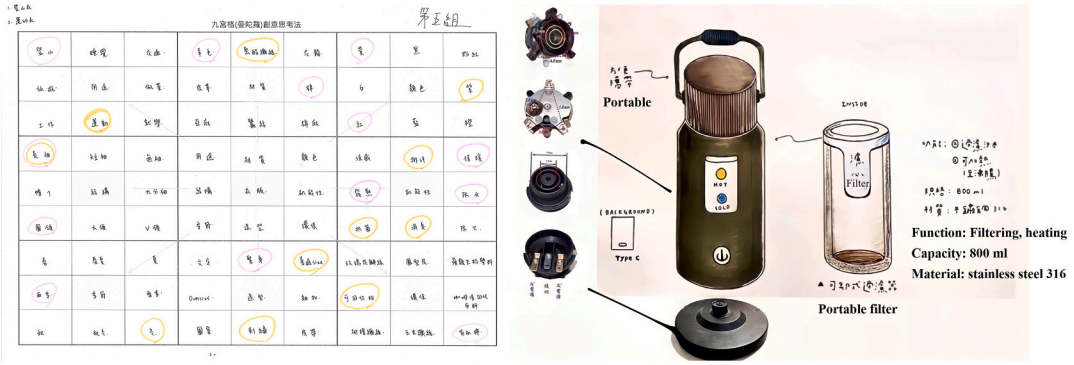
Students' attitudes and learning in gamification are positive. It can be seen from the descriptions of students' responses, such as "stimulated much imagination," "fun/interesting," "want to learn more," and "increased communication skills."

4.3. Results of AHP

In this study, paired comparisons of objectives and alternatives were conducted using Excel software. As a result, 15 questionnaires passed the consistency test (CR is less than 0.1). The weights and rankings were calculated for all items, and the results are presented in Table 3, Table 4, Table 5, and Table 6. Students considered collaboration skills more important than the other two objectives. In addition, the effectiveness of alternatives (teaching methods) was evaluated regarding objectives. The results showed that the most effective teaching method for enhancing creativity was the SCAMPER technique, the most effective for enhancing collaboration skills was balloon competition, and the most effective for enhancing communication skills was Mandala thinking.

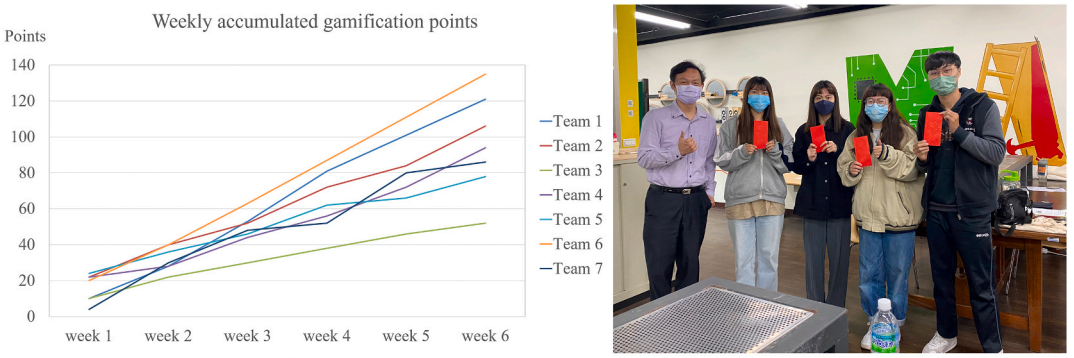
Finally, this study established global weighting and ranking based on the results of the aforementioned hierarchical analysis, as shown in Table 7, and the results showed that the most effective teaching method for the overall goal was Mandala thinking.

Fig. 6. SCAMPER worksheet and results.



(a) (b)

Fig. 7. Implementation results of Mandala thinking: (a) Nine-square grid worksheet; (b) Concept sketches of the automatic temperature control thermos.



(a) (b)

Fig. 8. Results of the gamification competition: (a) Points accumulated per week; (b) Cash rewards.

Table 2
Student self-assessment results.

Self-assessment survey items	Mean	S.D.
More prefer gamification to traditional lectures.	5.38	1.16
Gamification can enhance creativity.	5.29	1.15
Gamification can enhance communication skills.	5.24	1.18
Gamification can enhance collaboration skills.	5.33	1.24
Gamification can stimulate learning interests.	5.33	1.15
Gamification can stimulate learning motivation.	5.24	1.04
Overall, gamification can enhance the learning outcomes of Creative and Innovative courses.	5.43	1.12

Table 3
Weights and rankings for objectives.

Objective	Local Weights	Ranking
Creativity	0.283	3
Collaboration skills	0.361	1
Communication skills	0.356	2
Total	1	(CR = 0.021)

5. Discussion

This study contributes to the research on enhancing learning by using multiple teaching methods in gamification. An essential finding of this study is the effectiveness of gamification. Each teaching method that fostered creativity in this study stimulated students to generate many novel and useful ideas, which meet the teaching goal and supports the idea that creativity can be taught [12]. The

Table 4
Alternatives weights and rankings – creativity.

Alternative	Local Weights	Ranking
Divergent thinking	0.178	4
Balloon competition	0.108	6
Method of focal objects	0.124	5
Forced relationships	0.193	2
SCAMPER technique	0.213	1
Mandala thinking	0.184	3
Total	1	CR = 0.050

Table 5
Alternatives weights and rankings – collaboration.

Alternative	Local Weights	Ranking
Divergent thinking	0.105	6
Balloon competition	0.307	1
Method of focal objects	0.11	5
Forced relationships	0.143	4
SCAMPER technique	0.153	3
Mandala thinking	0.182	2
Total	1	CR = 0.048

Table 6
Alternatives weights and rankings – communication.

Alternative	Local Weights	Ranking
Divergent thinking	0.142	5
Balloon competition	0.1750	2
Method of focal objects	0.117	6
Forced relationships	0.148	4
SCAMPER technique	0.1748	3
Mandala thinking	0.243	1
Total	1	CR = 0.052

Table 7
Ratings for the alternatives on goal and each objective.

Alternative	creativity	collaboration	communication	Goal	
	Local Weight	Local Weight	Local Weight	Global Weights	Global Ranking
Divergent thinking	0.178	0.105	0.142	0.1388	5
Balloon competition	0.108	0.307	0.1750	0.2038	2
Method of focal objects	0.124	0.11	0.117	0.1165	6
Forced relationships	0.193	0.143	0.148	0.1590	4
SCAMPER technique	0.213	0.153	0.1748	0.1776	3
Mandala thinking	0.184	0.182	0.243	0.2043	1
Total	1	1	1	1	

gamification process stimulated a fun and competitive atmosphere and learning environment and established good teacher-student interaction, which helped students learn. Furthermore, according to the student responses, gamification stimulated their learning motivation, attitudes, and interest, corresponding to the findings of Mula-Falcón [124] and Marasco [96]. The students also perceived that gamification enhanced their creativity, collaboration, and communication skills. They preferred to use gamification in traditional lectures and any other courses. These findings respond to the first research question of this study.

Another essential finding of this study is the identification of the most effective teaching methods from students' perspectives. The results showed that Mandala thinking was the most effective for the overall goal, consistent with Chang's findings [38]. That research indicated that Mandala thinking is more efficient in stimulating new and unique ideas for Taiwanese students. However, this result may vary by student background or student size, as the difference in global weights between Mandala thinking and balloon competition was minimal (only 0.0005).

In addition, this study also found the most effective teaching methods regarding the three learning objectives of creativity, collaboration, and communication skills. The results indicated that the SCAMPER technique was the most effective teaching method for enhancing creativity. Balloon competition was the most effective teaching method for enhancing collaboration skills, and Mandala

thinking was the most effective teaching method for enhancing communication skills. For each learning objective, the most effective teaching method is different. In addition, the weights of the SCAMPER technique and Mandala thinking were ranked in the top three for each objective. MFO, in contrast, was the least effective teaching method. The above results can be used to answer the second research question of this study and provide an essential reference for selecting effective teaching methods to enhance learning.

Finally, an unexpected finding was that the learning objective students considered most important differed from the one set by the teacher. This result demonstrates that educators should first understand students' needs when dealing with diverse students so that they can set appropriate learning objectives to enhance learning effectively [125,126].

6. Conclusions

This study implemented gamification and six teaching methods for enhancing creativity. It aimed to examine the effects on students' creativity, collaboration, and communication skills and to identify more effective teaching methods corresponding to the learning objectives from students' perspectives. The results showed that (1) students perceived that gamification enhanced their creativity, collaboration, and communication skills; (2) students considered that gamification could stimulate their motivation, attitudes, and interest in learning; (3) the gamification process created a fun, competitive atmosphere and learning environment that facilitated student learning; (4) for the overall goal, Mandala thinking was the most effective teaching method; and (5) for the creativity, collaboration, and communication skills learning objectives, the most effective teaching methods were the SCAMPER technique, balloon competition, and Mandala thinking, respectively. The results of this study make significant contributions that reinforce previous studies and provide essential references for selecting effective teaching methods that meet teaching objectives.

7. Limitations and future research

This study has several limitations. First, teaching to enhance creativity was only conducted for six weeks. It is a relatively short time and may need to be increased for students to fully understand each teaching method to reach knowledge sharing, internalization, and creation [127]. Second, the order of implementation of multiple teaching methods can only be scheduled based on teachers' past experiences. However, the order of implementation of teaching methods may affect the results. Third, most students in the course did not know each other at the beginning of the semester. Unfamiliarity among students may interfere with learning. Fourth, our study was limited by a relatively small sample size comprising only students enrolled in the course. Further empirical testing with a larger and more diverse sample is warranted to enhance the generalizability of our findings. Fifth, only student self-report data were analyzed in this study. Various response biases may have affected the results. Finally, the gamification process can only be as fair as possible. Reasons that may affect the fairness of team scores, such as different team sizes (groups of 4 or 5), absenteeism, and differences in personal characteristics and prior experience, are beyond the instructor's control.

Research on gamification in education is still in its infancy [90]. Based on the above findings and limitations, this study suggests that more in-depth research can be conducted in the following directions: (1) The implementation time of teaching creativity can be planned for more extended periods or different periods for each teaching method to examine whether enhancing creativity is more effective. A more extended period may allow students to develop knowledge sharing, internalization, and creation that would help enhance creativity [127]. (2) Future research could include more teaching methods that enhance creativity or change the order of teaching methods. Scott [128] identified 11 common types of creativity training, and different creativity teaching methods may have different results. (3) Different gamification elements and mechanisms may affect the results [129]. The impact of different designed gamification elements or mechanisms on learning still needs further research. (4) Expanding the scope of the study to include larger sample size and conducting empirical testing with participants from diverse contexts would enhance the study's comprehensiveness by providing a broader perspective and generating richer data for analysis. (5) Fairness and student indifference can affect results during gamification. Therefore, research on designing fairer teaching strategies and improving student indifference should be conducted to avoid negative results on learning.

Author contribution statement

Kuo-Wei Lee: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Data availability statement

The data that has been used is confidential.
Supplementary content related to this article has been published online at [URL].

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e20420.

References

[1] G.T. Dow, *Defining Creativity*, in *Creativity And Innovation*, Routledge, 2022, pp. 5–21, https://doi.org/10.4324/9781003233923.
[2] R.J. Sternberg, Creating a vision of creativity: the first 25 years, Psychol. Aesthetics, Creativ. Arts (1) (2006) 2–12, https://doi.org/10.1037/1931-3896.S.1.2.
[3] A. Egan, et al., Developing creativity in higher education for 21st century learners: a protocol for a scoping review, Int. J. Educ. Res. 82 (2017) 21–27, https://doi.org/10.1016/j.ijer.2016.12.004.
[4] S. Greiff, C. Niepel, S. Wüstenberg, 21st century skills: international advancements and recent developments, Think. Skills Creativ. 18 (2015) 1–3, https://doi.org/10.1016/j.tsc.2015.04.007.
[5] T.d.C. Nakano, S.M. Wechsler, Creativity and innovation: skills for the 21st century, Estud. Psicolog. 35 (3) (2018) 237–246, https://doi.org/10.1590/1982-02752018000300002.
[6] S. Ko, J.E. Butler, Creativity: a key link to entrepreneurial behavior, Bus. Horiz. 50 (5) (2007) 365–372, https://doi.org/10.1016/j.bushor.2007.03.002.
[7] R. Kumar, S. Shukla, Creativity, proactive personality and entrepreneurial intentions: examining the mediating role of entrepreneurial self-efficacy, Global Bus. Rev. 23 (1) (2019) 101–118, https://doi.org/10.1177/0972150919844395.
[8] H. Sarooghi, D. Libaers, A. Burkemper, Examining the relationship between creativity and innovation: a meta-analysis of organizational, cultural, and environmental factors, J. Bus. Ventur. 30 (5) (2015) 714–731, https://doi.org/10.1016/j.jbusvent.2014.12.003.
[9] T.B. Ward, Cognition, creativity, and entrepreneurship, J. Bus. Ventur. 19 (2) (2004) 173–188, https://doi.org/10.1016/s0883-9026(03)00005-3.
[10] B. Arora, Chapter 6: How to Introduce and Integrate Creativity, Edward Elgar Publishing, 2019, pp. 57–65, https://doi.org/10.4337/9781788975087.00018.
[11] G. Scott, L.E. Leritz, M.D. Mumford, The effectiveness of creativity training: a quantitative review, Creativ. Res. J. 16 (4) (2004) 361–388, https://doi.org/10.1080/10400410409534549.
[12] E.P. Torrance, Can we teach children to think creatively?*, J. Creativ. Behav. 6 (2) (1972) 114–143, https://doi.org/10.1002/j.2162-6057.1972.tb00923.x.
[13] V.P. Glaveanu, J.C. Kaufman, A historical perspective, in: The Cambridge Handbook of Creativity, second ed., Cambridge University Press, Cambridge, 2019, pp. 9–26, https://doi.org/10.1017/9781316979839.
[14] W. Li, On the role of creativity in the application-oriented university students' engagement and success, Heliyon 9 (6) (2023), e17374, https://doi.org/10.1016/j.heliyon.2023.e17374.
[15] X. Gu, et al., Stimulating creativity: examining the effectiveness of four cognitive-based creativity training techniques, J. Creativ. Behav. 56 (3) (2022) 312–327, https://doi.org/10.1002/jocb.531.
[16] X. Huang, Striving for better teaching and student creativity development: linking informal workplace learning and teaching for creativity, Think. Skills Creativ. 41 (2021), https://doi.org/10.1016/j.tsc.2021.100889.
[17] M.B. Calavia, T. Blanco, R. Casas, Fostering creativity as a problem-solving competence through design: think-Create-Learn, a tool for teachers, Think. Skills Creativ. 39 (2021), https://doi.org/10.1016/j.tsc.2020.100761.
[18] T. Cremin, K. Chappell, Creative pedagogies: a systematic review, Res. Pap. Educ. 36 (3) (2019) 299–331, https://doi.org/10.1080/02671522.2019.1677757.
[19] M. Khatibi, A. Badeleh, R. Khodabandelou, A bibliometric analysis on the research trends of gamification in higher education: 2010-2020, The New Educ. Rev. 65 (3) (2021) 17–28, https://doi.org/10.15804/tner.21.65.3.01.
[20] M. Kalinauskas, Gamification in fostering creativity, Soc. Technol. 4 (1) (2014) 62–75, https://doi.org/10.13165/st-14-4-1-05.
[21] W. Oliveira, et al., Tailored Gamification in Education: A Literature Review and Future Agenda, Education and Information Technologies, 2022, https://doi.org/10.1007/s10639-022-11122-4.
[22] I. Caponetto, J. Earp, M. Ott, Gamification and education: a literature review, in: European Conference on Games Based Learning, Academic Conferences International Limited, 2014.
[23] G.B. Esquivel, Teacher behaviors that foster creativity, Educ. Psychol. Rev. 7 (2) (1995) 185–202, https://doi.org/10.1007/bf02212493.
[24] R.A. Beghetto, Creative learning in education, in: The Palgrave Handbook of Positive Education, 2021, pp. 473–491, https://doi.org/10.1007/978-3-030-64537-3_19.
[25] L. Khikmah, *Teachers Creativity in designing learning activities: sustaining students motivation.* English review, J. English Educ. 7 (2) (2019), https://doi.org/10.25134/erjee.v7i2.1639.
[26] J. Krath, L. Schürmann, H.F.O. von Korflesch, Revealing the theoretical basis of gamification: a systematic review and analysis of theory in research on gamification, serious games and game-based learning, Comput. Hum. Behav. 125 (2021), https://doi.org/10.1016/j.chb.2021.106963.
[27] G. Barata, et al., Improving student creativity with gamification and virtual worlds, in: Proceedings of the First International Conference on Gameful Design, Research, and Applications, 2013, pp. 95–98, https://doi.org/10.1145/2583008.2583023.
[28] D. Alt, N. Raichel, Enhancing perceived digital literacy skills and creative self-concept through gamified learning environments: insights from a longitudinal study, Int. J. Educ. Res. 101 (2020), https://doi.org/10.1016/j.ijer.2020.101561.
[29] B. Bourke, Using gamification to engage higher-order thinking skills, in: Handbook of Research on Promoting Higher-Order Skills and Global Competencies in Life and Work, 2019, pp. 1–21, https://doi.org/10.4018/978-1-5225-6331-0.ch001.
[30] S. Parjanen, M. Hyypiä, Innotin game supporting collective creativity in innovation activities, J. Bus. Res. 96 (2019) 26–34, https://doi.org/10.1016/j.jbusres.2018.10.056.
[31] T. Taesotikul, C. Chinpaisal, S. Nawanopparatsakul, Kahoot! gamification improves learning outcomes in problem-based learning classroom, in: 2021 3rd International Conference on Modern Educational Technology, , Association for Computing Machinery, Jakarta, Indonesia, 2021, pp. 125–129, https://doi.org/10.1145/3468978.3468999.
[32] S. Nadi-Ravandi, Z. Batooli, Gamification in education: a scientometric, content and co-occurrence analysis of systematic review and meta-analysis articles, Educ. Inf. Technol. 27 (7) (2022) 10207–10238, https://doi.org/10.1007/s10639-022-11048-x.
[33] S. Pozo-Sánchez, G. Lampropoulos, J. López-Belmonte, Comparing gamification models in higher education using face-to-face and virtual escape rooms, J. N. Approaches Educ. Res. 11 (2) (2022), https://doi.org/10.7821/naer.2022.7.1025.
[34] S.E. Bonner, Choosing teaching methods based on learning objectives: an integrative framework, Issues Account. Educ. 14 (1) (1999) 11–15, https://doi.org/10.2308/iace.1999.14.1.11.
[35] M.-N. Tsai, et al., A brainstorming flipped classroom approach for improving students' learning performance, motivation, teacher-student interaction and creativity in a civics education class, Think. Skills Creativ. 38 (2020), https://doi.org/10.1016/j.tsc.2020.100747.
[36] Ö. Göçmen, H. Coşkun, The effects of the six thinking hats and speed on creativity in brainstorming, Think. Skills Creativ. 31 (2019) 284–295, https://doi.org/10.1016/j.tsc.2019.02.006.
[37] V.M.Y. Cheng, Infusing creativity into Eastern classrooms: evaluations from student perspectives, Think. Skills Creativ. 6 (1) (2011) 67–87, https://doi.org/10.1016/j.tsc.2010.05.001.
[38] Y. Chang, et al., Investigating the synergy of critical thinking and creative thinking in the course of integrated activity in Taiwan, Educ. Psychol. 35 (3) (2014) 341–360, https://doi.org/10.1080/01443410.2014.920079.

[39] H. Xu, J. Hamari, How to Improve Creativity: a Study of Gamification, Money, and Punishment, Behaviour & Information Technology, 2022, pp. 1–15, https://doi.org/10.1080/0144929x.2022.2133634.
[40] J.H. Lee, M. Portillo, Transferability of creative self-belief across domains:The differential effects of a creativity course for university students, Think. Skills Creativ. 43 (2022), https://doi.org/10.1016/j.tsc.2021.100996.
[41] E. Susetyarini, E. Nurohman, H. Husamah, Analysis of students' collaborative, communication, critical thinking, and creative abilities through problem-based learning, Jurnal Penelitian dan Pengkajian Ilmu Pendidikan: e-Saintika 6 (1) (2022) 33–42, https://doi.org/10.36312/esaintika.v6i1.584.
[42] A. Rahardjanto, H. Husamah, A. Fauzi, Hybrid-PjBL: learning outcomes, creative thinking skills, and learning motivation of preservice teacher, Int. J. InStruct. 12 (2) (2019) 179–192, https://doi.org/10.29333/iji.2019.12212a.
[43] D. Aguilera, J. Ortiz-Revilla, STEM vs. STEAM education and student creativity: a systematic literature review, Educ. Sci. 11 (7) (2021), https://doi.org/10.3390/educsci11070331.
[44] K.J. Duncan, Examining the effects of immersive game-based learning on student engagement and the development of collaboration, communication, creativity and critical thinking, TechTrends 64 (3) (2020) 514–524, https://doi.org/10.1007/s11528-020-00500-9.
[45] H.Y. Liu, Promoting creativity of nursing students in different teaching and learning settings: a quasi-experimental study, Nurse Educ. Today 108 (2022), 105216, https://doi.org/10.1016/j.nedt.2021.105216.
[46] S.R. Jónsdóttir, Narratives of creativity: how eight teachers on four school levels integrate creativity into teaching and learning, Think. Skills Creativ. 24 (2017) 127–139, https://doi.org/10.1016/j.tsc.2017.02.008.
[47] I. Giannopulu, et al., Synchronised neural signature of creative mental imagery in reality and augmented reality, Heliyon 8 (3) (2022), e09017, https://doi.org/10.1016/j.heliyon.2022.e09017.
[48] E. Papaleontiou- Louca, et al., Teaching for creativity in universities, J. Educ. Hum. Dev. 3 (4) (2014), https://doi.org/10.15640/jehd.v3n4a13.
[49] M. Karwowski, School Does Not Kill Creativity, European Psychologist, 2021, https://doi.org/10.1027/1016-9040/a000449.
[50] D.K. Simonton, Teaching creativity, Teach. Psychol. 39 (3) (2012) 217–222, https://doi.org/10.1177/0098628312450444.
[51] S.-Y. Chen, et al., Effect of project-based learning on development of students' creative thinking, Int. J. Electr. Eng. Educ. 59 (3) (2019) 232–250, https://doi.org/10.1177/0020720919846808.
[52] A. Craft, Creativity in Schools, 2005, https://doi.org/10.4324/9780203357965.
[53] L.T. Nguyen, et al., How teachers manage their classroom in the digital learning environment - experiences from the University Smart Learning Project, Heliyon 8 (10) (2022), e10817, https://doi.org/10.1016/j.heliyon.2022.e10817.
[54] V.M.Y. Cheng, Tensions and dilemmas of teachers in creativity reform in a Chinese context, Think. Skills Creativ. 5 (3) (2010) 120–137, https://doi.org/10.1016/j.tsc.2010.09.005.
[55] X. Huang, J.C.-K. Lee, X. Dong, Mapping the factors influencing creative teaching in mainland China: an exploratory study, Think. Skills Creativ. 31 (2019) 79–90, https://doi.org/10.1016/j.tsc.2018.11.002.
[56] M. Goyal, C. Gupta, V. Gupta, A meta-analysis approach to measure the impact of project-based learning outcome with program attainment on student learning using fuzzy inference systems, Heliyon 8 (8) (2022), e10248, https://doi.org/10.1016/j.heliyon.2022.e10248.
[57] L.M. Davies, L.D. Newton, D.P. Newton, Creativity as a twenty-first-century competence: an exploratory study of provision and reality, Educ. 3-13 46 (7) (2017) 879–891, https://doi.org/10.1080/03004279.2017.1385641.
[58] A.B. Saebø, L.A. McCammon, L. O'Farrell, Creative teaching—teaching creativity, Caribb. Q. 53 (1–2) (2016) 205–215, https://doi.org/10.1080/00086495.2007.11672318.
[59] G. Göksu, Yaratıcılığı öğretmek için yaratıcı olmak: yaratıcılıklarına ilişkin öğretmenlerin ve öğretim elemanlarının öz-değerlendirmeleri, Ankara Üniversitesi Eğitim Bilimleri Fakültesi Dergisi 50 (2) (2017) 225–253, https://doi.org/10.1501/Egifak_0000001403.
[60] A.S. Hosseini, University student's evaluation of creative education in universities and their impact on their learning, Proc. - Soc. Behav. Sci. 15 (2011) 1806–1812, https://doi.org/10.1016/j.sbspro.2011.04.007.
[61] D.R. Mullet, et al., Examining teacher perceptions of creativity: a systematic review of the literature, Think. Skills Creativ. 21 (2016) 9–30, https://doi.org/10.1016/j.tsc.2016.05.001.
[62] A. Ahern, et al., Critical thinking in the university curriculum – the impact on engineering education, Eur. J. Eng. Educ. 37 (2) (2012) 125–132, https://doi.org/10.1080/03043797.2012.666516.
[63] H.-C. Kuo, Y.-C. Tseng, Y.-T.C. Yang, Promoting college student's learning motivation and creativity through a STEM interdisciplinary PBL human-computer interaction system design and development course, Think. Skills Creativ. 31 (2019) 1–10, https://doi.org/10.1016/j.tsc.2018.09.001.
[64] N. Radclyffe-Thomas, Fashioning cross-cultural creativity: investigating the situated pedagogy of creativity, Psychol. Aesthetics, Creativ. Arts 9 (2) (2015) 152–160, https://doi.org/10.1037/aca0000014.
[65] A. Valquaresma, J.L. Coimbra, Searching for creativity in the Portuguese preschool and basic education curricula, Curric. J. 33 (3) (2022) 460–477, https://doi.org/10.1002/curj.140.
[66] E. Marquis, S. Vajoczki, Creative differences: teaching creativity across the disciplines, Int. J. Scholarsh. Teach. Learn. 6 (1) (2012), https://doi.org/10.20429/ijsotl.2012.060106.
[67] R.G. Garcia-Caceres, A.E. Delgado-Tobon, J.W. Escobar-Velasquez, Selection of learning strategies supported on SMAA-M, Heliyon 8 (2) (2022), e08978, https://doi.org/10.1016/j.heliyon.2022.e08978.
[68] J.P. Guilford, The Nature of Human Intelligence, 1967.
[69] A.C. Neubauer, et al., The self-other knowledge asymmetry in cognitive intelligence, emotional intelligence, and creativity, Heliyon 4 (12) (2018), e01061, https://doi.org/10.1016/j.heliyon.2018.e01061.
[70] W. Zhang, Z. Sjoerds, B. Hommel, Metacontrol of human creativity: the neurocognitive mechanisms of convergent and divergent thinking, Neuroimage 210 (2020), 116572, https://doi.org/10.1016/j.neuroimage.2020.116572.
[71] C. Stevenson, et al., Putting GPT-3's Creativity to the (Alternative Uses) Test, 2022, https://doi.org/10.48550/arXiv.2206.08932 arXiv preprint arXiv: 2206.08932.
[72] L.S. Colzato, A. Ozturk, B. Hommel, Meditate to create: the impact of focused-attention and open-monitoring training on convergent and divergent thinking, Front. Psychol. 3 (2012) 116, https://doi.org/10.3389/fpsyg.2012.00116.
[73] T. Wujec, The Marshmallow Challenge, vol. 12, Retrieved November, 2010, p. 2013.
[74] O. Niebuhr, Advancing higher-education practice by analyzing and training students' vocal charisma: evidence from a Danish field study, 7th Int. Conf. Higher Educ. Adv. (HEAd'21) (2021) 1–8, https://doi.org/10.4995/HEAd21.2021.12827.
[75] F. Rueckert, Engineering as an educational tool: restructuring conceptual physics, 2015 ASEE Ann. Conf. Expos. Proc. (2015) 26, https://doi.org/10.18260/p.23953, 615.1-26.615.7.
[76] C.S. Whiting, Creative Thinking. Reinhold Management Science Series, Reinhold : Chapman & Hall, 1958.
[77] Y.V. Shuhailo, T.M. Derkach, Project-based learning for undergraduate engineering students minoring in textile technology and design, J. Phys. Conf. 1840 (1) (2021), https://doi.org/10.1088/1742-6596/1840/1/012042.
[78] M.A. Orloff, Methods of inventing, in: Inventive Thinking through TRIZ: A Practical Guide, Springer Berlin Heidelberg, Berlin, Heidelberg, 2003, pp. 14–45, https://doi.org/10.1007/978-3-662-08013-9_2.
[79] W.E. Souder, R.W. Ziegler, A review of creativity and problem solving techniques, Res. Manag. 20 (4) (2016) 34–42, https://doi.org/10.1080/00345334.1977.11756427.
[80] M.Ö. Yazar Soyadı, The effectiveness of SCAMPER technique on creative thinking skills, J. Educ. Gifted Young Sci. 4 (1) (2016) 31, https://doi.org/10.17478/jegys.2016116348, 31.
[81] T.-T. Wu, Y.-T. Wu, Applying project-based learning and SCAMPER teaching strategies in engineering education to explore the influence of creativity on cognition, personal motivation, and personality traits, Think. Skills Creativ. 35 (2020), https://doi.org/10.1016/j.tsc.2020.100631.

[82] R.F. Eberle, Developing imagination through scamper*, J. Creativ. Behav. 6 (3) (1972) 199–203, https://doi.org/10.1002/j.2162-6057.1972.tb00929.x.
[83] O. Serrat, The SCAMPER technique, in: Knowledge Solutions, 2017, pp. 311–314, https://doi.org/10.1007/978-981-10-0983-9_33.
[84] S.Y. Huang, et al., Creative thinking counseling teaching program can improve the creativity, creative tendency, and self-concept of grade 7 students: a quasi-experimental study, J. Creativ. Behav. 55 (3) (2021) 819–838, https://doi.org/10.1002/jocb.491.
[85] S. Deterding, et al., From game design elements to gamefulness, 11, in: Proceedings of the 15th International Academic MindTrek Conference on Envisioning Future Media Environments - MindTrek, 2011, pp. 9–15, https://doi.org/10.1145/2181037.2181040.
[86] Z. Luo, Gamification for educational purposes: what are the factors contributing to varied effectiveness? Educ. Inf. Technol. 27 (1) (2021) 891–915, https://doi.org/10.1007/s10639-021-10642-9.
[87] A.N. Saleem, N.M. Noori, F. Ozdamli, *Gamification Applications in E-learning: a literature review*. Technology, Knowl. Learn. 27 (1) (2021) 139–159, https://doi.org/10.1007/s10758-020-09487-x.
[88] L.F. Rodrigues, A. Oliveira, H. Rodrigues, Main gamification concepts: a systematic mapping study, Heliyon 5 (7) (2019), e01993, https://doi.org/10.1016/j.heliyon.2019.e01993.
[89] J. Kim, D.M. Castelli, Effects of gamification on behavioral change in education: a meta-analysis, Int. J. Environ. Res. Publ. Health 18 (7) (2021), https://doi.org/10.3390/ijerph18073550.
[90] S. Hakak, et al., Cloud-assisted gamification for education and learning – recent advances and challenges, Comput. Electr. Eng. 74 (2019) 22–34, https://doi.org/10.1016/j.compeleceng.2019.01.002.
[91] Y.B. Mohammed, F. Ozdamli, Motivational effects of gamification apps in education: a systematic literature review, BRAIN Broad Res. Artif. Intell. Neurosci. 12 (2) (2021), https://doi.org/10.18662/brain/12.2/196.
[92] J. Xu, et al., Psychological interventions of virtual gamification within academic intrinsic motivation: a systematic review, J. Affect. Disord. 293 (2021) 444–465, https://doi.org/10.1016/j.jad.2021.06.070.
[93] E. Ratinho, C. Martins, The role of gamified learning strategies in student's motivation in high school and higher education: a systematic review, Heliyon 9 (8) (2023), https://doi.org/10.1016/j.heliyon.2023.e19033.
[94] I. Aldalur, A. Perez, Gamification and discovery learning: motivating and involving students in the learning process, Heliyon 9 (1) (2023), e13135, https://doi.org/10.1016/j.heliyon.2023.e13135.
[95] A. Skaržauskienė, M. Kalinauskas, Fostering collective creativity through gamification, in: The Proceedings of the ISPIM Americas Innovation Forum: Montreal, 2014. *Canada on 5-8 October 2014*.
[96] E. Marasco, L. Behjat, W. Rosehart, Integration of gamification and creativity in engineering design, 2015 ASEE Ann. Conf. Expos. Proc. (2015) 26, https://doi.org/10.18260/p.24334, 997.1-26.997.9.
[97] R. Queirós, M. Pinto, The Dangers of Gamification, Springer Nature Switzerland, Cham, 2022, https://doi.org/10.1007/978-3-031-20319-0_12.
[98] C. Dichev, D. Dicheva, Gamifying education: what is known, what is believed and what remains uncertain: a critical review, Int. J. Educ. Technol. Higher Educ. 14 (1) (2017), https://doi.org/10.1186/s41239-017-0042-5.
[99] Z. Zainuddin, et al., The impact of gamification on learning and instruction: a systematic review of empirical evidence, Educ. Res. Rev. 30 (2020), https://doi.org/10.1016/j.edurev.2020.100326.
[100] E. Mårell-Olsson, Using gamification as an online teaching strategy to develop students' 21st century skills, Interac. Design Architect.(s) (47) (2021) 69–93, https://doi.org/10.55612/s-5002-047-004.
[101] H.Y. Kwon, K. Özpolat, The dark side of narrow gamification: negative impact of assessment gamification on student perceptions and content knowledge, Inf. Trans. Educ. 21 (2) (2021) 67–81, https://doi.org/10.1287/ited.2019.0227.
[102] M.D. Hanus, J. Fox, Assessing the effects of gamification in the classroom: a longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance, Comput. Educ. 80 (2015) 152–161, https://doi.org/10.1016/j.compedu.2014.08.019.
[103] C. Almeida, M. Kalinowski, B. Feijo, A systematic mapping of negative effects of gamification in education/learning systems, 2021 47th Euromicro Conf. Softw. Eng. Adv. Appl. (SEAA) (2021) 17–24, https://doi.org/10.1109/seaa53835.2021.00011. Palermo, Italy.
[104] A.M. Toda, P.H.D. Valle, S. Isotani, The Dark Side of Gamification: an Overview of Negative Effects of Gamification in Education, Springer International Publishing, Cham, 2018, https://doi.org/10.1007/978-3-319-97934-2_9.
[105] O.S. Vaidya, S. Kumar, Analytic hierarchy process: an overview of applications, Eur. J. Oper. Res. 169 (1) (2006) 1–29, https://doi.org/10.1016/j.ejor.2004.04.028.
[106] Y. Wind, T.L. Saaty, Marketing applications of the analytic hierarchy process, Manag. Sci. 26 (7) (1980) 641–658, https://doi.org/10.1287/mnsc.26.7.641.
[107] T.L. Saaty, Decision making with the analytic hierarchy process, Int. J. Serv. Sci. 1 (1) (2008) 83–98.
[108] W. Andang, R. Efendi, AHP method for determining the right teaching method for mathematics subjects: metode ahp untuk menentukan metode pengajaran yang tepat pada mata pelajaran matematika, Int. J. Technol. Vocat. Educ. Train. 2 (2) (2021) 44–49, https://doi.org/10.46643/ijtvet.v2i2.130.
[109] S. Yang, M. Arif, Optimization of English Classroom Quality Evaluation Model with AHP, vol. 2022, Security and Communication Networks, 2022, pp. 1–9, https://doi.org/10.1155/2022/2502377.
[110] D. Li, W. Zhao, Research on Teaching Quality Evaluation System Based on Improved AHP, 2021, https://doi.org/10.25236/icited.2021.067.
[111] T.R. Sahroni, H. Ariff, Design of analytical hierarchy process (AHP) for teaching and learning, 2016 11th Int. Conf. Knowl., Info. Creativity Supp. Syst. (KICSS) (2016) 1–4, https://doi.org/10.1109/kicss.2016.7951412.
[112] R. Dorado, et al., An AHP application to select software for engineering education, Comput. Appl. Eng. Educ. 22 (2) (2014) 200–208, https://doi.org/10.1002/cae.20546.
[113] M. Raadabadi, et al., Prioritizing the factors influencing effective teaching from the viewpoint of students: the use of analytical hierarchy process (AHP), Iran. J. Med. Educ. 12 (11) (2013) 817–825.
[114] N. Kim, J. Park, J.-J. Choi, Perceptual differences in core competencies between tourism industry practitioners and students using Analytic Hierarchy Process (AHP), J. Hospit. Leisure Sports Tourism Educ. 20 (2017) 76–86, https://doi.org/10.1016/j.jhlste.2017.04.003.
[115] Y.-M. Huang, et al., The design and implementation of a meaningful learning-based evaluation method for ubiquitous learning, Comput. Educ. 57 (4) (2011) 2291–2302, https://doi.org/10.1016/j.compedu.2011.05.023.
[116] K.F. Geisinger, 21st century skills: what are they and how do we assess them? Appl. Meas. Educ. 29 (4) (2016) 245–249, https://doi.org/10.1080/08957347.2016.1209207.
[117] E. Alsadoon, A. Alkhawajah, A.B. Suhaim, Effects of a gamified learning environment on students' achievement, motivations, and satisfaction, Heliyon 8 (8) (2022), e10249, https://doi.org/10.1016/j.heliyon.2022.e10249.
[118] I. Doney, Research into effective gamification features to inform e-learning design, Res. Learn. Technol. 27 (0) (2019), https://doi.org/10.25304/rlt.v27.2093.
[119] P. Anunpattana, et al., Capturing potential impact of challenge-based gamification on gamified quizzing in the classroom, Heliyon 7 (12) (2021), e08637, https://doi.org/10.1016/j.heliyon.2021.e08637.
[120] F. Fauzi, M. Erna, R. Linda, The effectiveness of collaborative learning throughtechniques on group investigation and think pair share students' critical thinking ability on chemical equilibrium material, J. Educ. Sci. 5 (1) (2021), https://doi.org/10.31258/jes.5.1.p.198-208.
[121] R. Lin, et al., Towards a sustainable distributed energy system in China: decision-making for strategies and policy implications, Energy, Sustain. Soc. 9 (1) (2019), https://doi.org/10.1186/s13705-019-0237-9.
[122] R. Velmurugan, S. Selvamuthukumar, R. Manavalan, Multi criteria decision making to select the suitable method for the preparation of nanoparticles using an analytical hierarchy process, Pharmazie 66 (11) (2011) 836–842, https://doi.org/10.1691/ph.2011.1034.
[123] T.L. Saaty, How to make a decision: the analytic hierarchy process, Eur. J. Oper. Res. 48 (1) (1990) 9–26, https://doi.org/10.1016/0377-2217(90)90057-i.
[124] J. Mula-Falcón, I. Moya-Roselló, A. Ruiz-Ariza, The active methodology of gamification to improve motivation and academic performance in educational context: a meta-analysis, Rev. Eur. Stud. 14 (2) (2022), https://doi.org/10.5539/res.v14n2p32.
[125] N. Noddings, Identifying and responding to needs in education, Camb. J. Educ. 35 (2) (2005) 147–159, https://doi.org/10.1080/03057640500146757.

[126] K.M.W. Mitchell, W.R. Manzo, The purpose and perception of learning objectives, J. Polit. Sci. Educ. 14 (4) (2018) 456–472, https://doi.org/10.1080/15512169.2018.1433542.
[127] Y.-c. Yeh, Y.-l. Yeh, Y.-H. Chen, From knowledge sharing to knowledge creation: a blended knowledge-management model for improving university students' creativity, Think. Skills Creativ. 7 (3) (2012) 245–257, https://doi.org/10.1016/j.tsc.2012.05.004.
[128] G. Scott, L.E. Leritz, M.D. Mumford, Types of creativity training: approaches and their effectiveness, J. Creativ. Behav. 38 (3) (2004) 149–179, https://doi.org/10.1002/j.2162-6057.2004.tb01238.x.
[129] P.-Z. Chen, T.-C. Chang, C.-L. Wu, Effects of gamified classroom management on the divergent thinking and creative tendency of elementary students, Think. Skills Creativ. 36 (2020), https://doi.org/10.1016/j.tsc.2020.100664.