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FOSTERING STUDENT'S CREATIVE AND PROBLEM-SOLVING SKILLS THROUGH A HANDS-ON ACTIVITY

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Abstract. *The purpose of this study is to investigate how a group of junior-high school pupils created a functional boat from scratch and resolved the problems encountered in a scientific project. The study was conducted using a qualitatively exploratory method. Data sources consist of artefacts, interviews, observations, and self-reflection reports. The study results reveal that the hands-on, trial-and-error experiential learning not only helped the pupils enhance their creative skills and problem-solving abilities, but also helped them realize the value of collaboration. Nevertheless, although they were able to make various shapes of boats using different materials, only half of the boats created were able to successfully complete the established course. It discloses that turning a model work into a functional piece demands a certain extent of scientific knowledge and skills associated with the tasks, in addition to creative skills. The students' anticipation of the teacher's scaffolding to achieve the project goal was found to vary greatly among teams, indicating a dilemma of the teachers' role in an open-form scientific project. How the created products were ranked in the project also raises concerns regarding setting up criteria to assess scientific artefacts. Suggestions for enhancing future implementations are provided.*

Key words: *boat creation, collaborative learning, hands-on skills, problem solving skills.*

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Introduction

Students nowadays are inclined to be an experiential, social, interactive, and activity-based generation (Oblinger & Oblinger, 2005). Experiential learning is regarded as an effective approach to assisting learning as it facilitates learners to transform experiences into knowledge. Kolb (1984) viewed learning as a continuous process grounded in experience involving constructing meaningful, applicable knowledge. The younger generation's preference for active, hands-on, social, collaborative learning helps lead to deeper levels of process and learning as they generate stronger connections (McGlynn, 2005). It is therefore important for educators to establish learning environments which are social, interactive, and learner-centred (Ramaley & Zia, 2005), and to provide more actively engaging experiential learning opportunities as well, to effectively enhance learning (McGlynn, 2005).

Creative ability is considered an important component of developing students' cognitive and problem-solving abilities (Plucker, Beghetto, & Dow, 2004). Eckhoff and Urback (2008) asserted that the process of exposing students to creative thinking, helps them confront problems yet to occur. A report issued by the National Advisory Committee for Creative and Cultural Education (NACCCE) (1999) states, that developing young people's creativity not only helps them develop their capacity for original ideas and action, but also prepares them to successfully cope with life in the twenty-first century. In Taiwan, because of the highly competitive entrance examinations, teaching practices tend to focus on cramming content knowledge, rather than establishing creative, active, social, and hands-on learning environments. Subsequently, students are prone to engage in rote learning. In the long run, this limits students' creative, problem-solving abilities and subsequent competitiveness. In order to promote students' potential in this regard, a boat creation project was implemented in a junior-high school, which allowed a group of pupils to engage in a social, active, hands-on learning activity.

Learning by Doing

The concept of learning by doing was initiated by John Dewey in his educational philosophy (1933, 1938). Dewey (1938) argued that students should learn from the situated world through continuous interaction with one another. In his view, a person's reflective thinking could not be separated from action, and critical reflection is an attempt to detach from the external world to construct meaning, but the validity of that meaning is always grounded in experience. Following Dewey's learning theory, Kolb (1984) defined learning as "the process whereby knowledge is created through the transformation of experience" (p.38). The process of experiential learning is dialectic. Kolb regarded learning as a continuous cycle of concrete experience, shifting to observation and reflection, developing abstract concepts, and then engaging in active experimentation. The ultimate objective is to facilitate learners' transfer of knowledge and skills, and use of new knowledge to make decisions and resolve problems. Hands-on activity positively affects students' understanding in learning science (Costu, Ünal, & Ayas, 2007) and also reinforces science instruction more effectively than traditional instruction (Sadi & Cakiroglu, 2011). Similarly, De la Hozi Casas and De Blas del Hoyo (2009) indicated that students learn more effectively by acting and observing the experimental results of their own actions, rather than listening to others' explanations about what they should learn.

Many educators urge that science has to be taught in a hands-on, inquiry-based way. Instead of textbook-based, factual knowledge oriented and lecture-driven science, experiential learning emphasizes experiment-based, idea-eliciting science learning through project teamwork (Payne, 2004). Encouraging investigative and hands-on science-based activities is regarded as a way of promoting the public understanding of science (NACCCE, 1999). For young learners, integrating imaginative and creative thinking into their existing knowledge can promote their potential for solving problems (Eckhoff & Urback, 2008). It is thus anticipated that a hands-on boat-creating learning activity will allow students to coordinate their current knowledge, creative skills, and problem-solving abilities.

Instruction and Pedagogical Strategies

Creative ability is intrinsically subject to the teaching of the academic disciplines, in addition to innovative thoughts (Rowlands, 2011). A teacher with creative capacity must be active and innovative, challenging and facilitating, and also an expert in his/her disciplinary area and pedagogical practice (McWilliam, 2009). Understanding students' learning needs and learning styles, such as the elements that influence their conceptions of the learning process, is critical (Cuthbert, 2005) when providing guidance and adopting instructional strategies to facilitate students to transform experiences into knowledge. In Thoonen et al.'s (2011) study, while the teachers regarded process-oriented instruction (e.g., focusing on knowledge building) and self-regulated learning as motivating for students, the students perceived them adversely. Rather, the students viewed cooperative learning methods and mastery goals as more motivating. Runco and Chand (1995) asserted, that it is more motivating and more meaningful if learners can choose their own tasks for creative thinking, as the process of problem identification would facilitate their intrinsic motivation. However, during the learning process, failure to provide sufficient learning support for less proficient or less able students could lead to perceivable loss of learning (Clark, 1989). Amabile (1996) reported that the outcome of an undertaken task can directly affect future engagement in tasks; those who fail are inclined not to engage in the same task again without reasonable feedback. Contrarily, those who achieve success are more likely to conduct the same task again if they are intrinsically motivated and the task itself is challenging. In other words, providing timely feedback to assist students to achieve the attempted learning objectives successfully will enhance their interest and future engagement. Likewise, Kirschenbaum (1998) contended that an assessment of creativity must be able to provide useful and helpful feedback to students to facilitate their creative functioning. Rook and Knippenberg (2011) found that participants were more likely to imitate when a creative exemplar was presented than when none was presented. They also argued that imitation helps improve creative performance, although it is at the expense of creativity.

New generation learners seem to appreciate structured activities that allow creativity (McGlynn, 2005). When promoting students' creativity, Simmons and Thompson (2008) contended that uniform lesson plans and standardized approaches restrain the development of creativity. When coping with new, novel information, it is better to explicitly show learners what to do and how to do it (Kirschner et al., 2006). While too much structure, such as providing a template for making an artefact, may restrain young learners' creativity and self-determination, too much freedom may engender confusion (Craft, 2007). Sagiv et al. (2009) examined creativity performance from

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the aspect of the relationship between personal cognitive style and structure of instruction, and found that those who preferred structured instructions demonstrated higher creativity than those who preferred free conditions when the scope of the task was limited, allowing them to concentrate on the key elements. Contrarily, those who were more intuitive appeared to perform better than their counterparts in a relatively free situation. That is, to enhance students' performance, the structure of the pedagogical process needs to suit their cognitive and learning styles. According to cognitive load theory, the free exploration of a highly complicated situation may bring about a heavy working memory load that is not advantageous to learning, which is particularly applicable to novice learners, who lack adequate schemas to integrate the new information into existing knowledge (Kirschner et al., 2006). Based on the notion of Vygotsky's zone of proximal development, adjusting instruction according to young learners' current level of ability helps stimulate their competence and conceptual understanding (Schmidt, 2011; Thoonen et al., 2011).

Environments Conducive to Creative Learning

In recent years, the conception of creativity has shifted from creative individual to creative team (McWilliam, 2009). According to the concept of group creativity, creativity is socially constructed (Reid & Petocz, 2004; Swede, 1993). Amabile (1996) indicated that a social environment supporting autonomy, competence, or task involvement helps promote learners' creativity. Kim (2009) reported that a flexible environment and active group interactions reinforce students' creativity. Feldhusen and Treffinger (1980) proposed suggestions for establishing a classroom environment favourable to creative thinking, including adapting to student interests and thoughts, giving time for students to develop their creative ideas, establishing a friendly, supportive atmosphere, allowing students to have choices, involving them in the decision-making process, and positively treating failure. The tips for teaching creativity authored by Sternberg and Williams (n.d.) indicate that promoting learners' self-regulation and encouraging creative collaboration can spur creativity. In short, a collaborative, flexible, social, thoughts-encouraging environment appears to be conducive to creativity. Moreover, a suitable seating arrangement was found to reinforce students' problem-solving skills in a collaborative setting (Heller & Hollabaugh, 1992). However, due to the preoccupations of the traditional classroom setting, classrooms are generally not seen as creativity-cultivating places (Furman, 1998). Thus, it was the attempt of the boat creation project investigated in the present study to be implemented in a collaborative, thought-provoking, active learning environment.

Purpose of Study

The purpose of this study is to investigate how these pupils created the boat from scratch and how they resolved the problems encountered (the learning process), and what artefacts they produced (the learning products) in the project. Three research questions are addressed in the study:

1. What and how had the pupils achieved from engaging in the project?
2. What were the challenges they encountered and how did they resolve them?
3. What was the teacher's role in helping the pupils fulfil the project goal?

Methodology of Research

Research Context

The participating subjects of this study were a group of 7th grade pupils studying in a junior high school in Taiwan, who joined the Innovative Club guided by a science teacher at the school. The major activity of the club was to design and produce scientific works, such as movable balloon cars and walking robots. Those who produced outstanding works would be encouraged to represent the school to participate in science related competitions held by outside institutions. In the year in which the study took place (2012), there were a total of 24 students from 14 different classes in the club, 11 of whom were female. The activity in the studied period was to construct an amphibious boat functional on an established course. The students formed eight teams, of which one had four members (Team 1), one had two (Team 2), and the remaining six had three each. The club members met weekly for 50 minutes in a designated project room for a total of 16 weeks.

Objectives of the Project

The domain knowledge associated with the project was related to the physics concepts of force and balance in Newtonian mechanics and electricity regarding electric circuits and the function of the motors. The pupils involved in the project were expected to be able to:

1. Create an amphibious boat through exerting imaginary potentials.
2. Resolve problems through connecting concepts associated with the boat construction to practice.

To allow the pupils more room for creativity, only basic materials were provided, consisting of 1 flat motor (approximately 3 cm long), 2 axles, 2 gears, 2 AA batteries, and 1 battery holder. In other words, the pupils had to decide on the remaining materials, including for the hull and wheels, and on the size and shape of the boat. Resolving the problems denotes that the pupils must test, observe, modify, reflect on, and retest the boat through trial-and-error experiments until it could complete the designated course. In addition, to suit the new generation's experiential learning preferences, more time was set aside for hands-on tasks, rather than listening to lectures.

Learning Activities

To facilitate student collaborative interaction, the teacher arranged the students to sit face-to-face, rather than in traditional rows, following Heller and Hollabaugh's (1992) assertion that face-to-face seating enhances team performance. The learning cycle proposed by Kolb (1976, 1984) was adopted to design the project, including concrete experience, observation and reflection, abstract concepts, and active experimentation.

1. Concrete experience: the students started with collaboratively designing a boat structure, assembling the motor piece with the collected materials, making wheels and oars, constructing the hull, and then connecting all the parts.
2. Observation and reflection: the students examined the created boat, observed any problems that occurred, and figured out solutions to resolve the problems.
3. Abstract concepts: it was anticipated that the students would gradually grasp the scientific concepts associated with making a boat. Specifically, they were expected to learn the concepts of force and balance embedded in the process of making the boat move forward (force) and straight (balance).
4. Active experimentation: it was also hoped that the students would be able to apply the learned concepts to construct a functional amphibious boat by trial and error. They would repeat the experiments until the boat could work as desired.

It is assumed, that through such learning activities, the students may better (1) connect theory to practice, (2) foster their problem-solving abilities, (3) improve their hands-on skills, and (4) learn collaborative skills through teamwork.

The Contest Rule

The teacher and pupils discussed and agreed upon a simple rule to rank the created boats in the contest: whichever boat went from the start to the finish line, in the shortest time would win. In other words, the final artefacts were assessed merely on their functionality (their speed), not their creativity (the aesthetics). Two contests two weeks apart were scheduled – a warm-up contest held in the 14th week and a final contest in the 16th week. A course composed of three parts – a land area, a water area, and a slope connecting the two, was built for the contests (see Figures 1 and 2). The land area was made of a 65x25cm piece of plastic board, the acrylic water tank was 80x25x20cm and was filled with 13 cm of water, and a 15x25cm metal board connected the two areas. Therefore, the boats had to be amphibious.

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Figure 1: The course.

Figure 2: The slope.

Data Collection and Analysis

Four sources of data were collected:

1. Artefacts: The boats made by the eight teams were collected.
2. Class observations: All class sessions, including the two contests, were videotaped to capture the students' dynamic interactions, particularly group interactions.
3. Interviews: A total of four group interviews with the students, two teams each, were administered after the final contest to acquire (1) the students' background, (2) team related information (e.g., the team leader's role, conceptions of the boat design, and team collaboration), (3) learning experiences (learning interests and challenges encountered), and (4) self-reflection. All interviews were digitally recorded.
4. Reflection reports: The students' end-of-project reports were collected to obtain their reflections on the activities. Three questions were addressed in their reports: (1) what went wrong in the two contests and why, (2) what could be improved and how, and (3) reflections from engaging in the activity.

All 24 students participated in the group interviews. The interview data were transcribed verbatim. Content analysis was adopted to analyse the qualitative data. The three types of codes, descriptive, interpretive, and pattern codes, addressed in Miles and Huberman (1994) were used to code and analyse the interview data. The transcriptions were coded paragraph by paragraph first to *describe* the overall picture of the data, followed by *interpretively* coding them, either statement by statement or paragraph by paragraph. General *patterns* or themes were then sought while reviewing the coded statements. The fundamental principle guiding the data coding process was that "it is not the words themselves, but their meaning that matters," as emphasized by Miles and Huberman (1994, 56). To increase the coding reliability, a graduate assistant and the researcher conducted the coding separately. The two sets of coding were compared and discussed until agreement was reached. The reflection reports were analyzed in three aspects, including 1) reasons for failure, 2) solutions to fix the problems, and 3) overall reflections on the entire learning process. All of the analysed data, including class observations, interviews, contest results, and reflection reports, were triangulated to strengthen their reliability and validity.

Results of Research

Firstly, the role of the teacher in the open-form project is described, followed by the contest results, and then the pupils' learning experiences.

The Teacher's Role

The class observation data show that the teacher adopted various pedagogical strategies to trigger the students' thoughts for creating the boat, including brainstorming, class-based discussions, mind-mapping activities, and six-hat thinking activities. The mind mapping activity was used to facilitate the students' conceptual mapping of the structure of the boat. In the six-hat thinking activity, the students were assigned to wear different coloured hats (representing different roles) to judge and assess the merits and drawbacks of the various designs proposed. Brainstorming and class-based discussions were conducted to solicit students' ideas and solutions for resolving the problems encountered (or which they might encounter) during the construction process; for example, how to resolve problems of leaking, wheel tilting, parts loosening, and the motor moving forward. Besides class-based discussions, the teacher also provided advice to individual teams to help them avoid possible problems she observed while circulating the classroom. For example, she reminded the students about adding oars to effectively propel the boat and connecting the battery to the motor correctly to ensure its movement. The class-based activities occupied approximately one-third of the 16-week sessions; the remaining time was set aside for the students to work in teams to collaboratively create their boats. According to the observation data, the structure mapping task appeared to be the most difficult for the majority of the students as it required them to embody an imaginary craft in graphic form with limited existing knowledge of force and balance prior to engaging in hands-on activities. After the conceptual structure stage was completed, the students became more active in the following hands-on tasks. In short, the teacher attempted to facilitate the students' conceptual understanding of the required knowledge of constructing a boat, rather than giving detailed, step-by-step instructions. It was the intention of the teacher to give the students room to construct the boat via hands-on trial-and-error experiments.

The Contest Results

In the first contest, only the boat created by Team 3 completed the course, taking a total of 5 seconds; five of the teams failed because the motor could not drive the boat forward, one did not fully complete their boat, and one forgot to bring their boat to the contest. In the final contest, four teams (Teams 1, 3, 4 and 6) succeeded and took 7, 5, 3, and 9 seconds to run through the course, respectively. Figures 3 to 6 display the four successful boats ranked from 1st to 4th place. The other four teams failed mainly due to gear (mechanics) and motor (electricity) problems (see Figures 7 to 10).

Figure 3: Team 4's styrofoam boat (1st place).

Figure 4: Team 3's styrofoam boat (2nd place).

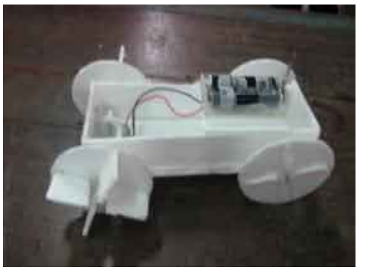

Figure 5: Team 1's pearl board boat (3rd place).

Figure 6: Team 6's styrofoam boat (4th place).

Figure 7: Team 2's initial boat.

Figure 8: Team 5's milk carton boat.

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Figure 9: Team 7's plastic bottle boat.

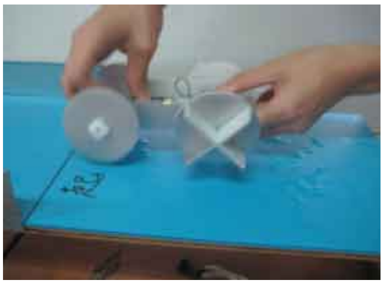

Figure 10: Team 8's pearl board boat.

As shown in the figures, the boats made by each team differed in style and material. The materials used to make the hull included styrofoam, pearl board, a milk carton and a plastic bottle. Pearl board was used by six of the teams for making wheels; one team (Team 6) chose plastic milk bottle caps and another one used styrofoam. The observation data indicate that all of the teams continuously modified their boat before and after the first contest, including changes in material, shape, and/or size. According to the interview data, the considerations for making the modifications consist of increasing thickness (e.g., replacing the foil hull with Styrofoam), easier cutting (e.g., replacing the styrofoam with pearl board), and easier propulsion (e.g., halving a hull). All of the teams added cross pieces as oars to either two or four of the wheels, reportedly to enhance the propelling force. Only one team (Team 4) did not add sides to its boat. After testing their boats, the students were more focused on the functional perspective of the modifications, rather than on its aesthetic appearance, when deciding on and changing the boats' materials and size. That is, the boat's appearance was eventually sacrificed for functionality. In addition, the content results reveal that turning a static artefact into a scientific functional work, appears to demand a certain extent of science knowledge and hands-on skills, in addition to initial creativity.

The Students' Learning Experiences

The interview data reveal that there were obvious differences among the teams regarding the time and effort they spent constructing their boats outside the class. Some of the teams (Teams 3 and 4) reportedly took turns working on the boat at home; the others (Teams 1, 2, and 6) modified and tested their boats in the project room, using their lunch breaks. The remaining teams, however, reportedly only worked during the club sessions; one of these teams did not actually test-run their boat in the course before the contests, but only tested it on the ground. It appears that those who succeeded in the final contest were those, who put more effort into completing the boat, with the exception of Team 2 (the group with two members). Consistently, the observation data reveal that not every team attended to the project tasks equally seriously. Members of some teams looked absent-minded while engaging in their tasks. The students' learning experiences are more clearly described below, including the process of their collaboration, the process of their problem-solving, and variations in learning needs.

The Process of Collaboration

In the interviews, the students were asked how they, as a team, initiated the boat design. Most of them stated that they decided on the materials and the shape through team discussions. Consideration of choosing materials consisted of their weight, feature, colour, and overall appearance. Most of the teams reportedly had their members choose tasks, each preferred to work on, such as making the hull, preparing the wheels, etc. The leader of Team 6, however, assigned members' tasks based on her judgment of their strengths. In addition, two students in Team 3 (the only successful team in the first contest) reported that they had a "dominating leader" who mostly decided everything for them. Regardless of choosing one's own tasks or being assigned certain tasks, most of the students reported that it took considerable negotiation among members for the project to progress. In the reflection reports, the majority of students reported that the collaborative tasks helped them learn social and negotiation skills; they also realized the importance of teamwork. One student in Team 4 (the winning team in the final contest) specifically wrote in his report, "Cooperation was the only way for the project to succeed."

Although group collaboration was recognized by most of the students as a critical element for the success of the teamwork, not all students had positive experiences with their team. For example, the two members in Team 2 stated in the interview, that the poor coordination of their team led to the failure of their boat. The class observation data also revealed that they twice forgot to bring their materials to the club due to misunderstandings and so could not continue their work during the club sessions. Similarly, two of the members in Team 3 stated, that although they were delighted to see their boat successfully complete the course in both contests, they did not feel that they contributed as much as they initially intended. They both wished that they could have chosen the tasks they preferred, rather than being assigned limited tasks by the leader. When this "dominating" student in Team 3 was asked about his task assignments and design ideas, he confidently said that he just intuitively knew what he wanted to do. He also stated that he did not have a habit of discussing his ideas, but preferred to think and work alone.

The Process of Problem-Solving

During the boat modification, in addition to class-based discussions, some teams reportedly followed the teacher's suggestions to alter their boat, whereas others combined the teacher's suggestions with their own judgment. Trial and error was used by most teams. The leader of Team 4 reported, that after the first contest they observed others' boats prior to making modifications. In order to fix the leaking, they closely observed Team 3 boat and made necessary changes to their own, including changing the hull material and adding a front board. When closely examining the boats made by Team 4 and Team 3 (see Figure 3 and Figure 4), the two boats do look somewhat alike. The leading student in Team 3 was asked why he put that piece of board in the front; he explained that it was meant to stabilize the boat when entering the water.

In their reflection reports, the students were able to identify what went wrong with their boats in the contests, and what modifications they made accordingly. The reported reasons for failure in the two contests included problems of gears sticking, uneven distances between the wheels, the motor and gears connection, wheel friction, sealing, short circuiting, and cutting, with gears and wheels the most commonly mentioned. The students also proposed solutions to fix the problems, such as placing the positive/negative battery connection correctly to ensure movement, adding oars adequately to increase the propulsion of the boat, drilling holes more precisely to better hold the wheels so as to enhance the balance of the boat while moving, choosing more appropriate materials like bottle caps as wheels for a smoother surface, strengthening sealing to avoid leaking, and enlarging the wheel size to increase the moving force. Although some of these details look rather trivial, resolving them appears to be how the students gained hands-on skills and attained scientific knowledge/conceptions of boat construction. A number of students emphasized that they felt a sense of accomplishment by being able to create a motored boat from scratch, regardless of whether they were successful or not.

Variations in Learning Needs

Even though the teacher adopted various pedagogical strategies to increase the pupils' knowledge and skills of making an amphibious boat, quite a few pupils mentioned in the interviews that the instructions were not sufficient to help them effectively construct a boat. They anticipated the shape of the boat, the size of the wheels, and the position of the motor and axles to be specified. Several reported that because of unclear instructions they were often puzzled about what to do and how to get some of the tasks done. One student in Team 2 commented that work that was too complicated might have a negative impact on student engagement, especially on those lacking good hands-on skills. On the other hand, most of the students who succeeded in getting their boats to complete the course, such as those in Teams 1, 3 and 4, tended to appreciate the freestyle creative project. Minimal instructions allowed them to engage in trial-and-error experiments and figure out various alternatives on their own. They also expressed a strong desire to remake the boat should they have another opportunity to do so. It is thus unsurprising that while some of the students suggested that more instruction had to be provided, others contended that less instruction was more appreciated and interesting. Likewise, provision of materials raised the same contention. While some students expressed that the materials used to construct the boat should be unified to ensure the fairness of the competition, others thought that it was more fun and challenging to decide one's own materials. These contentions reflect a dilemma regarding the teacher's role in terms of providing guidance and setting up assessment in an open-form creative project.

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Discussion

The teacher used various pedagogical approaches to facilitate the students' learning, including brainstorming, mind-mapping activities, and six-hat thinking activities initiated by De Bono (1987). By following the learning cycle addressed by Kolb (1984), the students were able to create, observe, modify, test, reflect on, and resolve problems encountered in the boat creation project. They eventually made various shapes of boat using different materials. The overall learning process appeared to have helped them cultivate creative, hands-on skills, and improve their problem-solving abilities. They also realized the value of collaboration and negotiation during teamwork. However, only half of the boats were able to successfully complete the course. Those who collaborated well were better able to achieve the project goal and appreciated the creative style of the project. Contrarily, those who were less able to meet the project requirements tended to desire more specific assistance. In other words, in addition to the students' own efforts spent on the project, whether the provided amount of instruction and guidance met their anticipations and learning demands also affected their final learning outcomes, reflecting the concept addressed in Vygotsky's zone of proximal development. The teacher, thus, plays an important role in perceiving students' learning needs and providing adequate assistance accordingly to help them accomplish the project goal, particularly in an open-form project.

Although collaboration was reported as an influential element affecting the teams' final learning outcomes, not all of the teams completed their works in such a manner. For example, the fact that the team (Team 3) with a "dominating" member successfully achieved the project goal seems to be highly associated with this particular student's intuition, personality and skills, rather than team collaboration, echoing Sagiv et al.'s (2009) argument that more intuitive students perform better in a freer condition. It is hence not surprising that the learning needs of more intuitive students are different from those who are more structure-oriented. Creative productivity involves many other aspects, including a creative personality embodied in behaviour traits which involve aptitudes, interest, attitudes, and temperament qualities (Guilford, 1950), independence of judgment, desire to take risks, and persistence and resilience in situations of adversity and failure (NACCCE 1999), and cognitive style, knowledge of heuristics, and work style (Amabile 1996). Although investigating students' creative tendencies and qualities was not the pursuit of the present study, future studies can delve into this area of research, particularly for helping young learners exert their potential creativity in advancing their learning achievements. Nonetheless, the results of this study verify that finding an appropriate balance between structure and freedom is not an easy matter and may rely on judgment, trial, and reflection, as mentioned by Craft (2007).

The class' decision to rank the created artefacts by speed raises the issue of setting up assessment standards. Even though the project was associated with the pupils' creative skills, the teacher and the students decided to rank the final artefacts merely by their functionality (their speed). Although quantitative measurements are more objective and less arguable, it may overlook many other values of the produced works, such as their aesthetics. Science itself may not be perceived as creative (Schmidt 2011); creating a boat in this case was regarded as a scientific activity, rather than a creative project in general. Such an assessment approach is not uncommon in Taiwan mainly due to the requirement of clear ranking of students' learning outcomes in the highly competitive examination systems. Consequently, student performance tends to be assessed based on objective criteria (e.g., exam scores, speed), rather than on subjective judgement (e.g., artistry, creativity, or parsimony). Subjectively judging and appreciating creative works, however, demands a certain extent of knowledge, insight, and an artistic mind, which deserves future research.

Conclusions

This study discloses that a hands-on, scientific project can foster students' creative and problem-solving skills. Cultivating students' skills in these regards, however, requires their conceptual understanding of the domain knowledge associated with the learning activities. Because of the various learning needs of the different teams, the varying degrees of effort exerted by each team, and the various work habits of the individual students, the teacher's role in the project becomes pivotal. More specifically, the teacher must be subtle and observatory with regard to the students' learning progress. How to help them reach their potential and maximize their learning outcomes through providing adequate instructions and appropriate creative room demands the teacher's subtle scaffolding and adequate pedagogical strategies.

Suggestions

To strengthen young students' overall learning outcomes in future implementations of open-form projects, the following suggestions are provided:

Providing more sophisticated instruction

As mentioned, in this study the students' anticipation of receiving instructions varied significantly. Clark (1995) contended that failing to provide adequate learning support for less proficient students could be detrimental to their learning, which seems to reflect the situation of some of the students in the studied project. Some researchers suggested that when the task is novel or when the learners are less experienced with the work, explicit guidance must be provided to assist them in achieving the intended objectives (e.g., Clark, 1989; Kirschner et al., 2006). Considering the students in the present study were 7th graders and were inexperienced with the required tasks, having them to prepare most of the parts and also cope with the problems with each part, was somewhat overwhelming for them. Besides, considering that half of the teams failed to complete the course, more sophisticated instruction and demonstrations, rather than minimal, conceptual guidance, is suggested. As Rowlands (2011) asserted, creative ability is intrinsically affected by the teaching of the academic disciplines, in addition to creative thoughts. Although more instruction may seem redundant to the more capable students, Clark (1982) contended that students may not suffer by learning less afterward, compared to prior instruction. Encouraging more able students to pursue advanced tasks, such as adding additional obstacles to the course, challenging their own records, and/or inviting them to present some effective strategies to the class, may allow them to continuously excel themselves.

Nurturing cooperation through assigning roles

The majority of the students in the present study agreed that cooperation was the best way to accomplish the project. Therefore, it is important to strengthen team cooperation. For young learners like 7th graders, more structured teamwork, rather than loosely organized cooperation, may be necessary. It is suggested that team members should be assigned specific roles to increase their sense of responsibility, as stated by Heller and Hollabaugh (1992). Runco and Chands (1995) asserted that it is more motivating to be able to choose one's own tasks. Most of the students in this project also appeared to prefer to choose their own work, rather than being assigned limited tasks by the leader. Therefore, it is recommended that the students themselves negotiate the aspect each of them is to be in charge of, such as the motor piece, axle and wheel parts, and hull and sides, and their related functions. It is also suggested that each team should be formed of at least three students to both reinforce group brainstorming and reduce each member's workload, echoing Heller and Hollabaugh's (1992) contention that the most appropriate number of team members is three to four. For 7th graders, the teacher may also need to follow up each team's progress by requiring them to submit brief periodic group reports describing each member's contribution, not only to ensure involvement, but also to gain social and negotiation skills.

Enhancing active sharing

In addition to teacher-led class-based activities, it is suggested that sharing activities should be held regularly allowing the students to actively share ideas and exchange thoughts about the ongoing tasks. The thoughts to be shared can include why each team chose certain materials to make their boat, how the members came up with their boat design, why they made certain modifications after the initial design, and how they resolved problems. Encouraging feedback from students in other teams is also important as reasonable feedback helps motivate students' future engagement (Amabile, 1996). Observing others' designs and even imitating the others' works is part of the process of creative thinking development (Rook & Knippenberg, 2011), particularly for young learners. Positively treating failure favours creative thinking (Feldhusen & Treffinger, 1980); therefore, it is also suggested that time should be set aside after the final contest for students in the successful teams to assist others in completing their unsuccessful artefacts, as this can cultivate positive attitudes, improve problem-solving abilities and enhance interaction skills.

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