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Construction and Development of iSTEM Learning Model

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ABSTRACT

This study integrates STEM education and imaginative education with project-based learning, and develops a set of "iSTEM (imagination, science, technology, engineering, mathematics) learning" methods in order to construct iSTEM ability indexes for vocational high school students and to explore the application and effectiveness of the learning model. This study employed the fuzzy Delphi method, a questionnaire survey, content analysis and focus group interviews and included 12 experts and 39 vocational high school students as the subjects. The important results obtained in this study are as follows: 20 iSTEM imagination ability indexes and 50 STEM integrated thinking and application ability indexes are constructed; a student-centered iSTEM learning model is developed; iSTEM learning activities can enhance the learning and integration of STEM knowledge; the iSTEM learning model produces a positive effect on integrated STEM thinking and the imagination ability of vocational high school students. Finally, this study puts forward recommendations for improving STEM education practices, teaching strategy design and high-level STEM ability assessment in the future.

Keywords: iSTEM learning model, STEM education, imaginative education

INTRODUCTION

STEM (science, technology, engineering, mathematics) is a new trend in international education curriculum reform; it is an interdisciplinary education integrating science, technology, engineering and mathematics. It stresses practical experience in real situations. In addition, it can be conducted through cooperative learning, inquiry-based teaching, teaching science and technology, multiple evaluation techniques and other learning strategies in order to encourage learners to inspect and integrate an understanding and application of science, technology, engineering and mathematics at any time (Lou, Tsai, and Tseng, 2011). The promotion of STEM education has gradually captured international attention. The education reform launched by the American Association for the Advancement of Science (AAAS) gives priority to motivating students to become proficient in science, technology and mathematics. The American Society for Engineering Education (ASEE) also set up the K-12 Engineering Research Center for the development of the integrated STEM teaching that has been implemented in primary schools, secondary schools and universities to kindle students' interest in science, mathematics, engineering and technology as well as future careers in STEM (Lou, Liu, Shih & Tseng, 2011). Additionally, the National Aeronautics and Space Administration (NASA), British Science Association (BSA), International Technology and Engineering Educators Association (ITEEA) and other institutions have also taken an active part in and integrated the development and promotion of STEM educational resources.

In engineering education, aside from refining technology and knowledgeability, research and development innovation skills are also a priority for Taiwan as it is faced with the current transformation in industry, nursing, scientific and technological talent needs. Therefore, developing students' imaginative thinking is the direction that current engineering education should strive for (Chiu, Chen, Lin, and Tu, 2012). Imagination could turn existing knowledge and experience into new knowledge or discovery, anticipate possible learning outcomes, and help to improve the flexible application of learning ability to life (Collins & Stevenson, 2004). In recent years, countries

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Contribution of this paper to the literature

- This study integrates STEM education and imaginative education into a new educational model - "iSTEM learning model". It provides a new direction and thinking for exploration-oriented STEM education.
- iSTEM learning model can encourage students to develop interest in engineering or technology programs and career orientation.
- The iSTEM ability indexes as the bases of curriculum development and evaluation.

have been actively involved in imagination training programs (Chiu et al., 2012; Ministry of Science and Technology, 2014). Taiwan also acknowledged that imagination was essential for future competitiveness and talent fostering and listed imaginative education as an important administration focus through the "Futures Imagination and Creativity in Education" medium-term plan promoted by the Ministry of Education, the "Integrating Imagination and Technology Research/Hands-On Ability Development" program and the "Integrating Imagination and Innovative Thinking into Engineering Education" talent development and research (Advisory Office, Ministry of Education Taiwan, 2012; Ministry of Science and Technology, 2009, 2014). Such promotion of research programs concerning imagination highlights the importance of imaginative education in educational policy, much of which incorporates imagination into the fields of science, technology, engineering and other areas. Therefore, it is worth exploring the promotion of integrating imaginative education into STEM education.

Based on the importance of imaginative education in the domain of engineering education, this study attempts to integrate STEM education and imaginative education into a new educational model with project-based learning – the "iSTEM learning model". Additionally, while developing and promoting the iSTEM learning model, clear learning ability indexes are developed to determine whether the presentation of knowledge met students' degree of learning and whether it provided a systematic learning basis (Yu, 2014). Thus, these authors constructed the iSTEM ability indexes as the basis of curriculum development and evaluation. In the meantime, a systematic curriculum model was developed and practical application and research at higher vocational colleges was conducted to verify the validity of the model.

On the basis of the above research motivation, the purposes of this study are as follows:

1. To construct ability indexes for "iSTEM Learning" for vocational high school students
2. To develop the model of "iSTEM Learning" for vocational high school students
3. To explore the impact of the iSTEM learning model on the learning effectiveness for vocational high school students

LITERATURE REVIEW

Theory and Research about STEM Education

STEM education is an interdisciplinary teaching method integrating science, technology, engineering, mathematics and other disciplinary knowledge, skills and beliefs (Baran, Billici, Mesutoglu & Ocak, 2016). STEM education regards hands-on learning and minds-on learning in the real-world context as the core value of STEM courses. The practice of engineering design and the application of science and technology offers students opportunities for hands-on learning. In addition, the systematic thinking of scientific exploration and mathematical analysis in the practical process guides students to integrate STEM knowledge and practice, find the relationship and connection between knowledge and problems, and hence develop their higher-level thinking ability (Fan and Yu, 2016; Herschbach, 2011). The STEM courses are expected to foster students' integrated knowledge base and flexible problem-solving skills so that students can learn how to create better solutions in the face of a rapidly changing future (Fan and Yu, 2016). As a result, in terms of teaching implementation, cooperative learning could be adopted and tasks or problems assigned so that students could probe into the problems, grasp the relevance of STEM knowledge, and also learn how to apply such knowledge to formulate feasible solutions for solving real-world problems during the course of problem solving (Chang and Yang, 2014).

By summarizing the studies on STEM, it was determined that STEM could flexibly integrate a wide range of "exploration-oriented" learning or teaching models (Lou, Tsai, Chen & Dzan, 2015; Lou, Tsai, Shih & Dzan, 2010; Lou, Tsai & Tseng, 2011; Lou, Diez, Hsiao, Wu & Chang, 2009; Lou, Liu, Shih, Chuang & Tseng, 2011; Lou, Liu, Shih & Tseng, 2011; Lou, Chung, Dzan, Tseng & Shih, 2013; Tseng, Chang, Lou & Chen, 2013; Lou, Tsai, Tseng & Shih, 2014). Specifically, the situated learning programs allow students to perform tasks related to Mars in the space laboratory, apply hands-on skills and virtual reality, integrate science and technology, and adopt critical thinking and expert guidance in order to encourage the exploration of STEM knowledge and enhance the development of such high-level abilities such as communication, cooperation, analysis and problem solving (Mathers, Pakakis &

Christie, 2011). In addition, due to its exploratory and hands-on characteristics, STEM could attract students to take part in practical activities in engineering design and could help to expand students' knowledge about and interest in STEM (Baran, Billici, Mesutoglu & Ocak, 2016). In addition, with respect to integrating a peer-led team learning program, students expressed their appreciation for conceptual learning and cooperative problem solving and recognized that with the leadership of experienced peers, insights could be yielded and supportive relationships could be developed (Kerri, Turvold, Erin, Mithra & Melissa, 2016).

To sum up, the application of STEM education emphasizes students' thinking ability in applying interdisciplinary integration and intellectual accomplishment to science, technology, engineering and mathematics. Based on the concept of learning by doing, STEM education attaches great importance to the students' hands-on process, employs the strategy of cooperative learning, and addresses real-world problems in real situations for interdisciplinary and integrated learning. In other words, STEM education places a high value on the application and connection of all disciplinary knowledge and problem solving, and resolving problems through practical applications can help students to gain abstract conceptual knowledge. As a result, this study concludes that STEM integrated thinking and application ability may include interdisciplinary integration, problem solving, scientific knowledge, technological knowledge, engineering knowledge, mathematical knowledge, cooperative learning, practice, application and other elements. In addition, because the learning motivations and driving force of professional interest are important sources of internal motivation for STEM, they are included as important dimensions of the ability scale.

Theory About and Research into Imaginative Education

Imagination refers to the ability to connect many different concepts and find their relationships. Different from the extraction of memory or mental imagery, imagination is the psychological process in which memories are reorganized in order to speculate and conceive of the possible form of new things (Horng, Wang, Shyr, Lee & Wang, 2013).

Through the exploration of the literature about imaginative education, the process of imagination was associated with the generation, use and transformation of imagination. Initially, this is based on life experience or the exploration of the relationship between present and past; that is, before the development stage of imagination, one should first increase his or her personal life experience in order to expand the mental image themes of imagination, establish a certain knowledge base, and explore and contemplate the past, present and future social, cultural background and experience. Lin (2011) mentioned, in the "Future Imagination Course and Teaching Model", that prior to imagination, the future should be first be considered to guide students to understand the relationship between and the cause and effect of the past and the present and to develop the ability to anticipate change. Second, the mental operation of imagination development starts. Students are engaged in the operation of spreading thinking; constantly diverging, breaking down, reorganizing, and connecting thinking; and using convergent thinking to gradually converge ideas into meaningful creative elements. Wang, Chu, Huang and Kang (2010) put forward the IDEAL imagination training model. 1) Initiation, referring to the generation of more new ideas and possibilities based on existing experience. 2) Development, guiding students to extend their imagination and expand upon new ideas drawn from the initial idea. 3) Alternative, guiding students to start from different perspectives, angles and directions and to actively throw themselves into the initiation of new work. 4) Links are based on "connections" and compare the various solutions in order to come up with the best solution.

Finally, students transformed the imagined results into specific object images via language, images, movement, works and other media. In the process of scientific imagination proposed by Ho, Wang & Cheng (2013), the final "virtual hands-on stage" specifies the results of refining the use of imagination by creating a prototype of works with novel ideas. To apply the mental operation involving conceptual, organized and structured ideas, students were guided to describe their specific ideas or make drawings and were encouraged to translate ideas into concrete actions.

In addition, positive emotions and motivations could encourage imaginative behaviors, and the implementation of imagination was often accompanied by positive psychological feelings. The emotional value mentioned by Wu, Chang, Chiu & Chen (2013) was an important feature of imaginative thinking, the emotional dimension of future imagination and the driving force of imagination. Chiu et al. (2012) included "imagination feelings" as one the imagination components, defining these as the happy, interesting and surprised feelings experienced after involvement in imagination activities.

In conclusion, this study summarizes the imagination ability indexes of iSTEM, which can include elements such as emotional motivations, psychological operation, concrete representation and other elements as important dimensions of the follow-up ability indexes.

RESEARCH METHOD AND DESIGN

Research Structure and Method

This study employed mixed-methods research. First, indexes were constructed in a quantitative manner. Then, the development learning model was designed with mixed quality research, and the data about on-site learning were cross-collected and verified. This study was conducted in three major parts. The first part involved the construction of the iSTEM imagination ability indexes, the second part included the development of the iSTEM learning model and the third part was designing and implementation of the teaching of iSTEM learning.

The research process and framework of this study are presented in **Figure 1**.

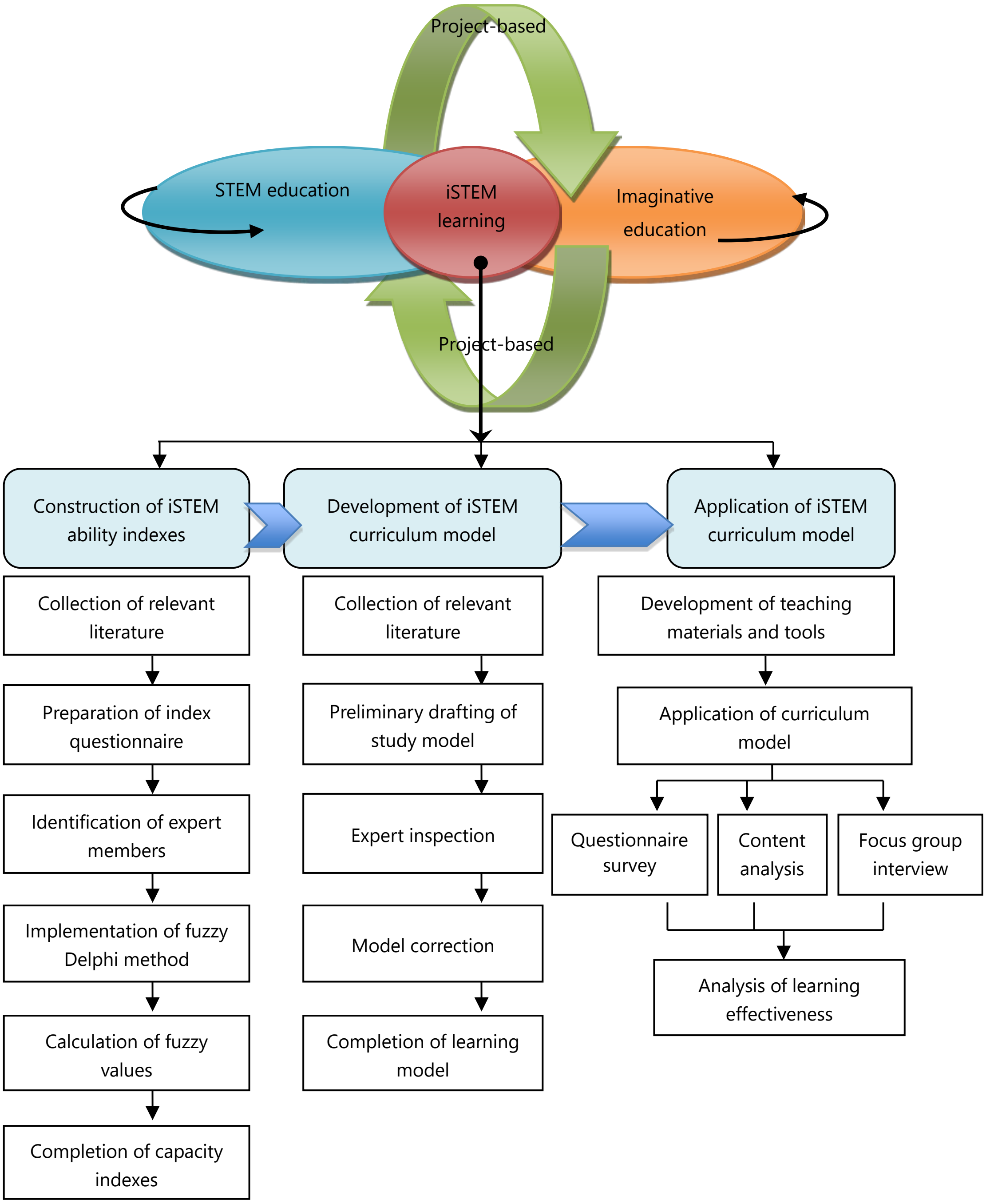


Figure 1. Research Framework

Fuzzy Delphi method

This study used the fuzzy Delphi method to construct iSTEM ability indexes. First, domestic and foreign information was garnered for exploration and used as a theoretical basis for the construction of the indexes, based on which the preliminary iSTEM ability indexes were developed. Second, the expert questionnaire was prepared to verify the applicability of the index structure prototype and revised as the questionnaire of experts' importance assessment. Subsequently, the questionnaire survey of the fuzzy Delphi method was carried out to complete the construction of the ability indexes and connotations.

This study defuzzified the fuzzy sets and first assumed the concept of membership functions of maximum and minimum sets to obtain the total membership values of the actual measured indexes. Then, the max-min method was adopted to integrate the assessment value of the fuzzy weights given by 12 experts, and after defuzzification, the right boundary value, left boundary value and total value were indicated by μR, μL and μT, respectively. The threshold value of μT was set to 0.6. If the total value was more than 0.6, this indicated that the expert group's index assessment importance degree was greater than 0.6 of consensus for index screening (Lu and Chang, 2013).

Questionnaire survey

This study adopted the "STEM integrated thinking and application ability questionnaire", "iSTEM imagination ability questionnaire" and "STEM knowledge ability test" as the tools to investigate the impact of iSTEM learning activities on students' integrated STEM thinking, application ability and imagination ability. "STEM integrated thinking and application ability questionnaire" and "iSTEM imagination ability questionnaire". The reliability of the scale was pretested through the purposive sampling of 133 subjects. The questionnaire was recovered for project analysis. After the inappropriate questions were eliminated, principal component analysis was employed for orthogonal rotation with varimax in order to extract factors. According to the STEM integrated thinking and application ability questionnaire, the factor loading of such dimensions as "behavioral driving force, psychological operation, cognition, cooperative learning and hands-on and application" were .76 ~.86, .66 ~. 82, .69 ~.81, .77 ~.84 and .88 ~.91, respectively; their Cronbach's α were .92, .95, .95, .93 and .91, respectively. According to the iSTEM imagination ability questionnaire, the factor loading of such dimensions as "emotional motivations, psychological operation and concrete representation" were 70 ~.81, .59 ~.84, and .64 ~.84, respectively; their Cronbach's α values were .93, .96, and .92, respectively. The STEM knowledge ability test was compiled by a professor with the Department of Naval Architecture and Ocean Engineering, Nation Kaohsiung Marine University. This test explored the theme of ships and was prepared based on such knowledge as science, technology, engineering and mathematics.

Content analysis

In the application of the iSTEM learning model, this study proposed to set up an online learning platform as students' blended cooperative learning context. Through this platform, interactive textual materials concerning the student subjects' learning were collected. Furthermore, the written reports, event photos and records, group works and other objects were analyzed in this study.

Focus group interview

This study applied a focus group interview for probing into the application and effectiveness of the iSTEM learning model. To collect in-depth and rich oral materials, the researchers, after using the interview outline on learning activities, selected the first three team members using purposive sampling and formed a focus group to carry out in-depth interviews. During the interviews, the researchers and participants described, discussed and debated the topics in the hope of gaining contextual and in-depth textual data for follow-up data analysis.

Research Subjects

Construction of high-level iSTEM ability indexes

The high-level iSTEM ability indexes constructed in this study include the "STEM integrated thinking and application ability index" and the "imagination ability index". To construct each index, 6 experts specializing in STEM education and 6 experts specializing in imaginative education were invited to assess the ability indexes.

Application of learning model

This study promoted and applied the iSTEM learning model in higher vocational colleges to verify the relevance and application effectiveness of such a learning model. On this basis, the research subjects of this study were vocational high school students who signed up for the "Turning the Key of Imagination Solar Pneumatic Ship Creative Design Contest". Thirty-nine subjects were divided into 10 groups with 3 to 4 people per group (GA ~ GJ).

Teaching design and implementation

The application of the iSTEM imagination learning model in this study adopted the theme of "Turning the Key of Imagination Solar Pneumatic Ship Creative Design Contest", which was held from May 18 to August 21, 2015. The promotion of activities was carried out in three stages, namely, a preparation stage, activity development stage and evaluation and feedback stage as described below:

Preparation stage (2015/5/18/-2015/6/5)

First, the activity theme of "Turning the Key of Imagination Solar Pneumatic Ship Creative Design Contest" was determined. Second, based on blended cooperative learning, the researchers planned the activity progress and content, developed driving questions and assessment standards, and set up a network platform (http://elearning.npust.edu.tw/moodle) as the learning context using Moodle. After the study tools were identified, at the initial stage of the research, the research subjects were gathered to set up the teams. Three to four people formed a team, and those with basic information literacy and a willingness to cooperate throughout the study were preferentially included. Then, a presentation was convened to explain the activity theme and content as well as the methodology for conducting the activities. Additionally, basic knowledge of ship building and skills in using the network platform were introduced in order to help students to quickly concentrate on the learning focuses. Before the start of the presentation, a pretest of knowledge about STEM was carried out.

Development stage (2015/6/6-2015/7/23)

This study divided the thematic activities into six task stages, namely, "exploration", "initiation", "development", "alternative", "links" and "presentation". Exploration refers to exploring the existing environmental and cultural background and acquiring knowledge about ships; initiation means starting from the existing experience, setting the starting point and goals of imagination and carrying out an exploration of knowledge about ships; development refers to expanding the imagination while analyzing the hull structure and conducting electromechanical configuration; alternative refers to a new starting point of development, or to using reverse thinking about the goals and conducting the assembly of and experimentation on the hull structure; links refers to converging and connecting all the ideas and to conferring new meanings in order to determine the themes and situations and embark on a design of the hull structure; and presentation is the visualization of the imagination, completion of the hull structure of the ship and carrying out a navigation test and corrections. There was approximately one week in which to fulfill each task, which was guided by driving questions and assignments. Each task stage utilized two-way feedback and could be added to and corrected at any time.

This study was conducted in the form of cooperative learning and stressed the groups' independent learning through team strength. The researchers played the roles of facilitators and helpers. Team interaction was carried out alternately in a face-to-face manner and using the network platform. The network platform provided group members with communication and interaction channels without space-time restrictions. Aside from the network interaction records, the researchers also encouraged students to translate physical interactions into texts and upload such texts to the platform to facilitate the storage and sharing of knowledge. In this way, the group discussions can be diversified, reflected and given feedback.

Assessment and feedback stage (2015/7/23-2015/8/21)

At the end of the activities, a wrap-up presentation was held and a questionnaire survey and focus group interview were carried out. Students needed to organize the activity process into a written report and briefing and share their works, imagination development and hands-on processes at the presentation. The research team evaluated students' imagination and scored their work performance test, verbal presentations, textual reports and online discussions and interactions in accordance with the works' modeling, design concepts and principle application.

RESEARCH RESULTS AND DISCUSSION

High-level iSTEM Ability Index

This study, by summarizing the findings in the literature, developed the preliminary framework for two types of high-level iSTEM ability indexes, that is, the "STEM integrated thinking and application ability index" and the "imagination ability index". Subsequently, an expert assessment of the fuzzy Delphi method was conducted. This study determined that the threshold value of the total value was greater than 0.6 for the screening and assessment index. Finally, 50 STEM integrated thinking and application ability indexes (detailed in **Figure 2**) and 20 iSTEM imagination ability indexes (detailed in **Figure 3**) were developed.

iSTEM Learning Model

The iSTEM learning model is based on integrated interdisciplinary concepts, selects a STEM topic with real-world applications, and divides learning activities into six stages including "exploration, initiation, development, alternative, links and presentation". Students can develop meaningful learning-by-doing on the basis of their own habits and needs and by means of cooperation in a mixed learning environment. **Figure 4** is a schematic diagram of the iSTEM learning model.

Task stage of the iSTEM learning model

The researchers organized the literature about imaginative education and maintain that the four stages "initiation, development, alternative and links" proposed by Wang, Chu, Huang and Kang (2010) covered the essentials of most imaginative education models and was the most complete understanding. As a result, the researchers regarded such stages as being the main structure of the iSTEM learning model. Furthermore, it is observed through the literature review that imagination is based on experience and that both imagination regeneration and generation were products of transforming, refining and innovating existing ideas or past experiences (Hsu et al., 2012). In addition, the concept and theory of imagination put forward by Vygotsky (2004) mentioned that the concepts created by imagination are based on the experience accumulated by individuals. The richer the individuals' experience is, the more abundant and diverse the imaginative materials they have available are. Moreover, imagination is also based on social experience, and unique experiences can be imagined through others' accounts to expand individual imagination elements (Tsau and Lin, 2012). Consequently, it can be learned that prior to imagining, the accumulation of individual experience and knowledge exploration are necessary and valuable, so the researchers added "exploration" to the first stage of the iSTEM learning model.

In addition, the transformation of imagination proposed by Liang, Hsu and Ling (2014) and the virtual hands-on stage put forward by Ho, Wang, Cheng (2013) both mentioned the meanings and actions of visualizing the abstract concept of imagination. Furthermore, the iSTEM learning model emphasizes the process of students' hands-on practice, so the researchers added the sixth stage, "presentation". To put it in another way, imagination was visualized, and the imagined situations produced through "exploration, initiation, development, alternative and links" were translated into actual works through hands-on practice.

The six task stages of the iSTEM learning model are presented as follows:

Exploration: Explore the existing environmental and cultural background and acquire knowledge about ships

The expansion of experience and knowledge is the basis for firing the imagination, so prior to imagination activities, the foundation and exploration of knowledge are of great importance. For this reason, the "exploration" stage of the iSTEM learning model was set to be the individuals' or groups' accumulation of basic knowledge (ship-themed knowledge about STEM); contemplation and analysis of the present, past and future environment; and understanding and analysis of materials. Using group GF as an example, the group explored and accumulated theoretical and practical knowledge about solar ships by means of investigation, material analysis and information collection (as shown in **Figure 5**, **6**, **7**).

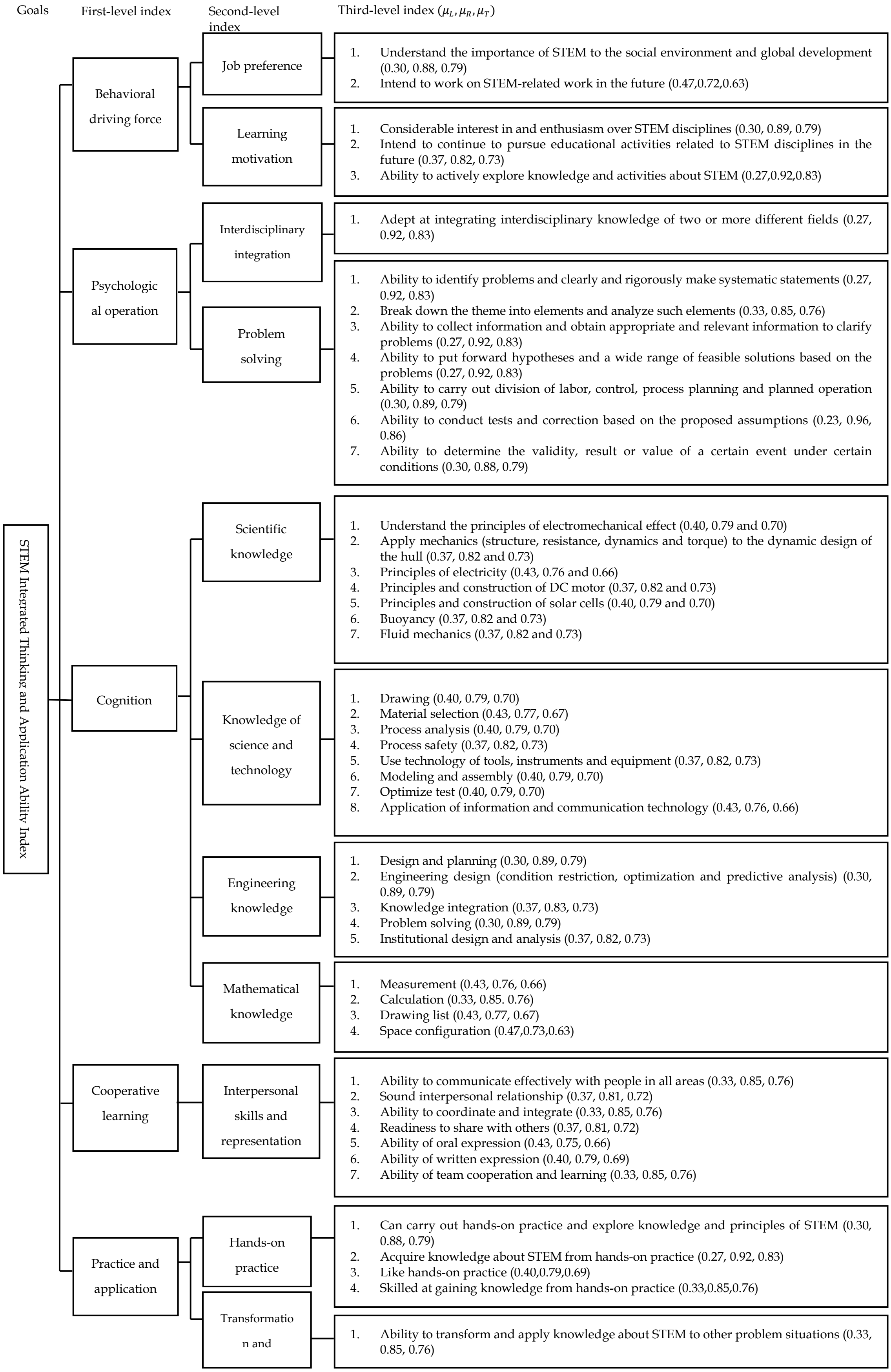


Figure 2. Tree Diagram of STEM Integrated Thinking and Application Ability Indexes

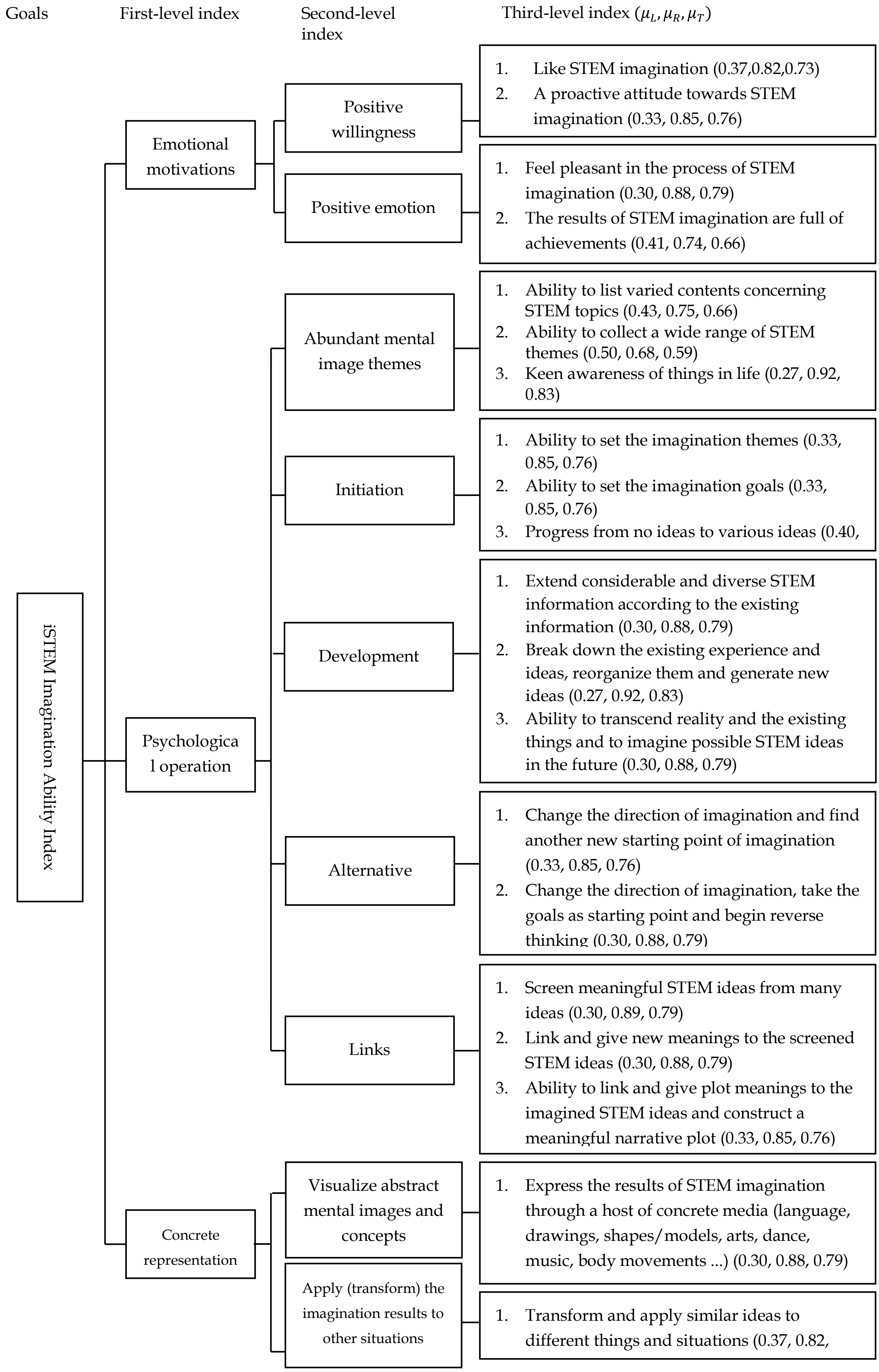


Figure 3. Diagram Tree of iSTEM Imagination Ability Indexes

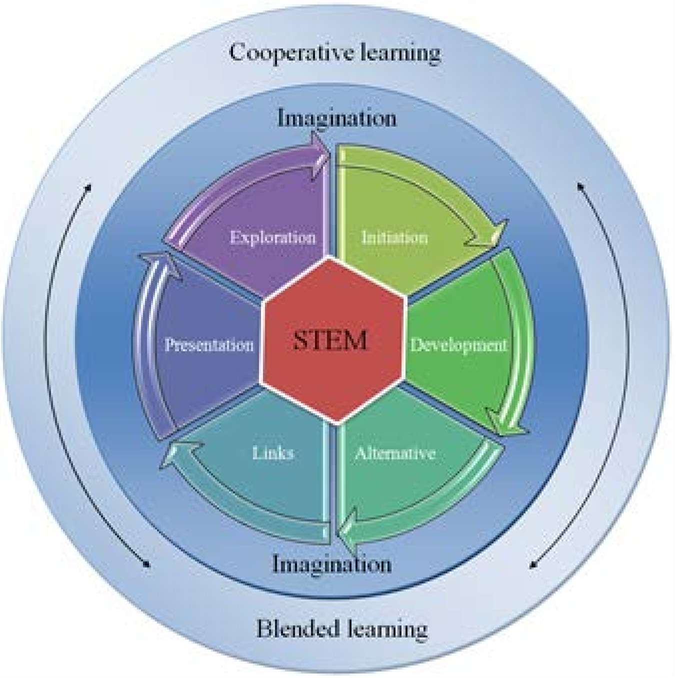


Figure 4. iSTEM Learning Model

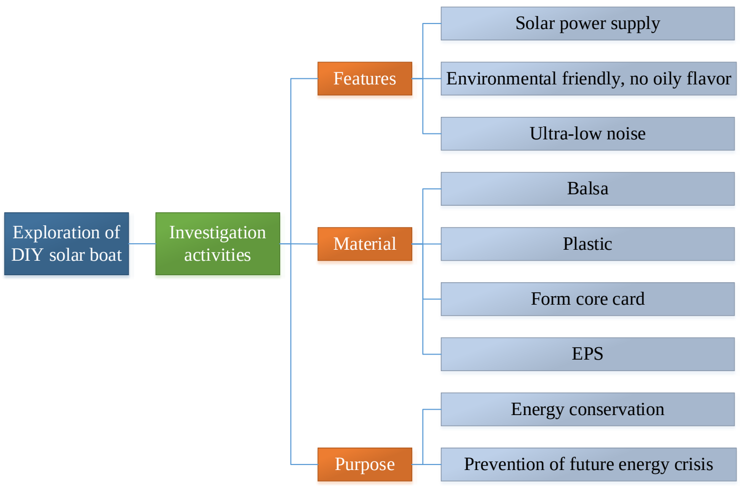


Figure 5. Imagination process of group GF at the exploration stage: Investigation activities

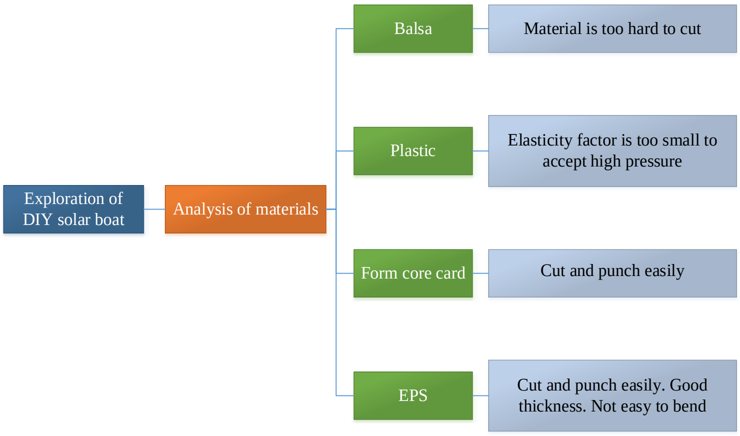


Figure 6. Imagination process of group GF at the exploration stage: Analysis of materials

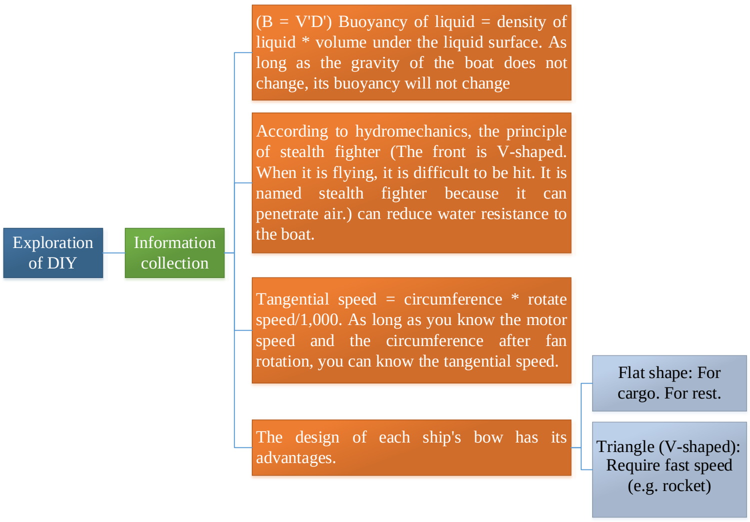


Figure 7. Imagination process of GF group at the exploration stage: Information collection

Initiation: Set a starting point and goals for the imagination based on existing experience and explore knowledge about ships

After accumulation, in the "exploration" stage, students accumulate a knowledge base and mental image themes while gradually forming a framework, developing ideas and a starting point, and developing goals for the imagination. Initiation was based on previous experience to produce the starting point of an idea, which could be a concept, an image or a plan (Wang et al., 2010). For example, group GF set two starting points including "ships and boats" and "applied principles and formulas" to initiate and set the goal of manufacturing a quality and efficient solar ship (as shown in **Figure 8**, **9**, **10**).

Development: Expand imagination, and meanwhile, analyze the hull structure and conduct electromechanical configuration

Development refers to constantly expanding the conceptualization of the original idea. Each initiation point is expanded to develop a vast range of possibilities. Aside from expanding imagination, some groups, in the process of development, also assess the possible outcomes of the idea as the basis for whether the concept should be developed in the future. In other words, the reasonableness and feasibility of each path is assessed so that ideas can be more focused. Students may further expand the imagination until the imagination is saturated with to feasible ideas. For instance, group GF, based on the starting point of "ships and boats", extended into such categories as "dynamic, materials, structure and types", and then developed ideas and kept spreading them. With respect to the starting point of "applied principles and formulas", the group developed and sorted concepts in accordance with science, technology, engineering and mathematics, during which the group gained more knowledge and understanding of STEM about ships and boats (as shown in **Figure 8**, **9**).

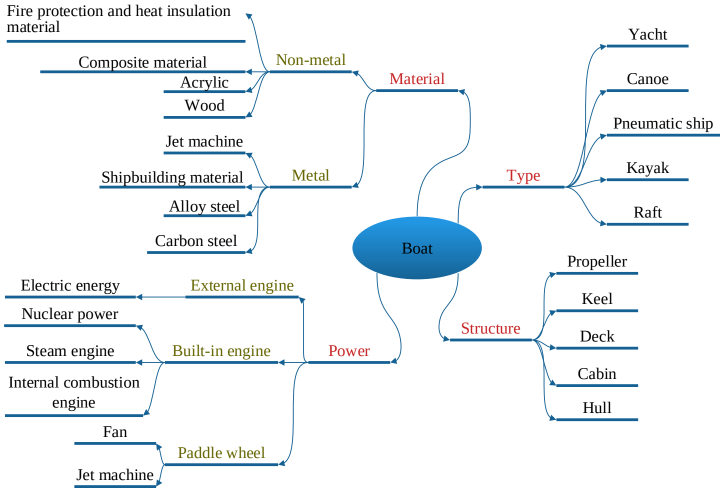


Figure 8. Imagination process of group GF at the initiation and development stages: Boat

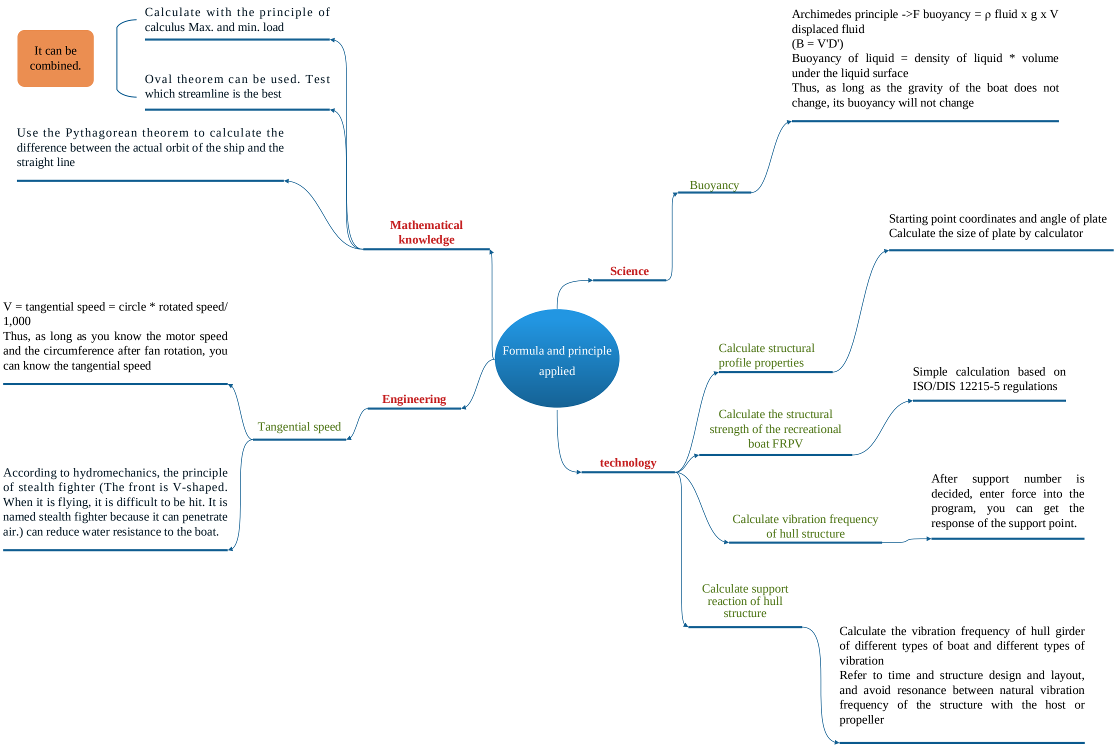


Figure 9. Imagination process of group GF at the initiation and development stages: Formula and principle applied

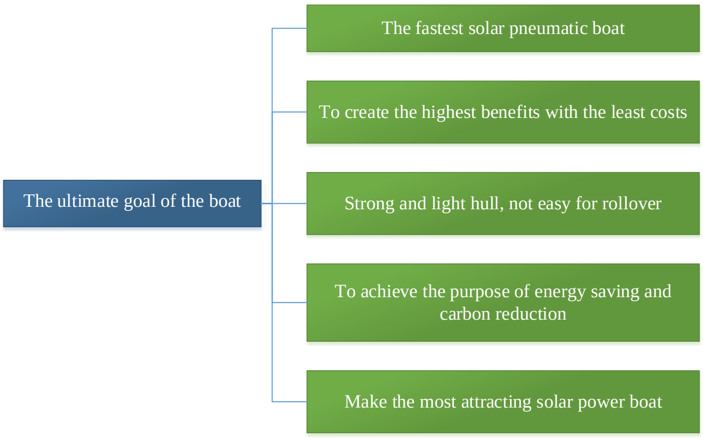


Figure 10. Imagination process of group GF at the initiation: The ultimate goal of the boat

Alternative: Develop new starting points, or conduct reverse thinking based on goals, and carry out assembly and experiment with the hull structure

When the ideas extended from the original initiation are saturated, then it is necessary to think or develop new starting points and ideas from different perspectives, or to conduct reverse thinking based on the goals to diversify the imagination. For instance, the hull developed according to the original idea by group GF had edges and corners (**Figure 11-a**). After the idea was changed, the group began again using a smooth angle and developed a competing model (**Figure 11- b**).

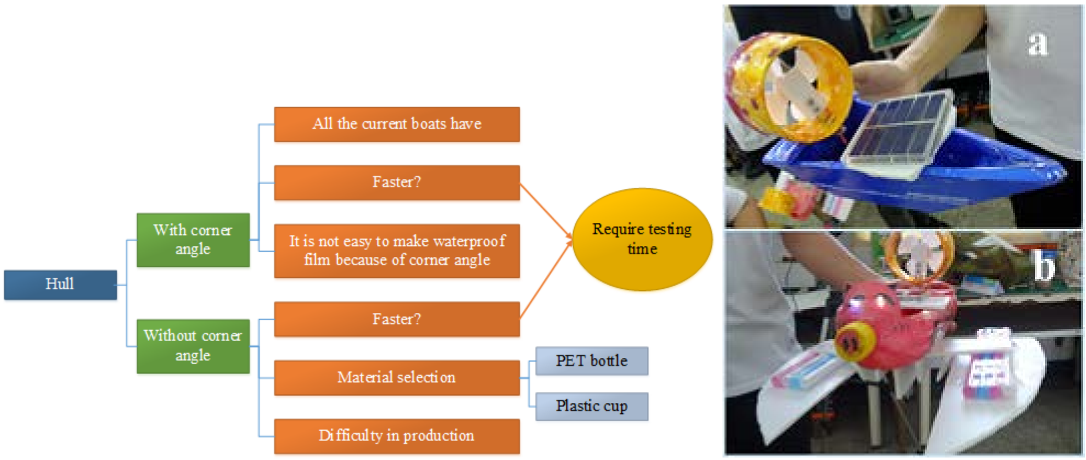


Figure 11. Schematic drawing of imagination process and hands-on practice of group GF at the alternative stage

Links: Link existing ideas and give them meaning, and embark on the design of the hull structure

After the stimulation of initiation, development, alternative and other stages, the network of ideas grows more abundant. "Links" means offering logical connections and meanings to the previous ideas. At this stage, students may assess the logic and the meaning of such ideas based on the existing materials and technical conditions. They can work out the most appropriate path through repeated hands-on practices and by putting the ideas into practice in the cross-verification of hands-on practice and ideas. For example, group GF measured the competing model, compared the hull performance, and eventually selected the smooth hull as the practical approach.

Presentation: Visualize imagination, complete the hull structure of the ship and carry out a navigation test and correction

Presentation visualizes the imagined images through hands-on practice. Students create an imaginative and efficient amphibious ship or a solar pneumatic ship according to the blueprint they developed and based on the existing technology, materials, cost and other conditions (as shown in **Figure 12**).

Figure 12. Hands-on Example of Solar Pneumatic Ship of Group GF

Characteristics and application of iSTEM imagination learning model

Blended cooperative learning strategy for facilitating learning

The iSTEM learning model integrates the face-to-face and network platform approaches into the students' learning situations, and students can make choices and develop their own learning plans and independently acquire knowledge based on their learning needs and habits. Meanwhile, when cooperating and learning with peers, students can inspire each other's ideas and learn together and thus develop "interpersonal intelligence" skills such as listening, acceptance and respect.

> *The group's strength was summoned up, and by pooling the wisdom of the group, complex and difficult topics could be simplified and even solved. (20150821.I.GG1)*
>
> *In a group, we must exchange our ideas with people of different personalities in order to kindle the spark of creativity, which is the most important lesson we learn in this activity. (20150821.I.GF2)*
>
> *We should learn to listen, get along with others and express ideas. (20150821.I.GA1)*

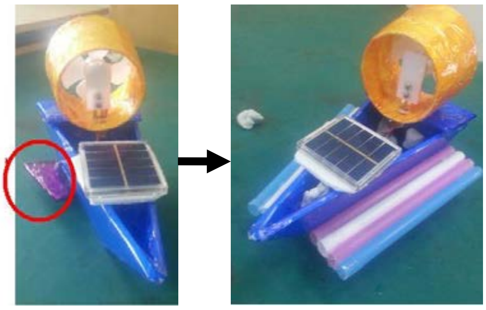
Involvement of network teaching assistants as facilitators of learning

In light of the education philosophy proposed by C. Rogers, teachers were the facilitators of learning, respected each learner as an independent individual with a sincere attitude, accepted students' emotions and opinions, and sympathized with students' learning processes without assessment or criticism (Lin, 1997, 68-69). Consequently, in the iSTEM learning model, the network teaching assistants intervened in learning as facilitators of learning, paid attention to students' learning initiative, and provided timely assistance and guidance with minimal intervention. Instead of excessive assessment or directly offering answers, they offered students more thinking space and self-learning opportunities with guided questions and emotional support. Rather than "teaching students", the teaching assistants make every endeavor to "facilitate" learning behaviors. It has been proved that a facilitating atmosphere can better stimulate creativity and exert a positive effect on inspiring imagination.

Imagination expands exploration and learning of STEM knowledge

A characteristic of the iSTEM learning model is the integration of imagination into STEM education so that acquisition and integration of STEM knowledge can be advanced to a higher level. We use group GA as an example of the application of scientific and technological knowledge to material selection (such as the use of a vacuum wall, nano-paint, air conditioning equipment and solar energy). To improve the effectiveness of the hull, scientific and mathematical knowledge was applied in the consideration and calculation of wind resistance, buoyancy and speed. Finally, the concept of engineering design is used to integrate science, technology, mathematics and other knowledge to design the hull shape and to resolve the problems with linking imagination and physical operation.

Table 1. Examples of Integration and Application of STEM Knowledge

Integration and Application of Knowledge	Knowledge Analysis
Increase the solar absorption positions -- "The absorption areas increase with aluminum foil, which can improve energy as well" (20150713.D.GB)	Science, technology and engineering
The propeller should form a 60-degree angle with the vertical surface or it can hit the water. If the motor produces enough horsepower, the propeller rotates more quickly and the propulsion power also increases correspondingly. The reason is that the electric current of the solar panels is 150 mA and that of a small motor suitable for power generation of solar panels is 70 mA. If one motor is used, then the motor can function most efficiently. In case of using two motors, the electric current supplied by the solar panels will be dispersed, so this is also the condition we take into consideration. (20150612.R.GG)	Science, technology, engineering and mathematics
At the bottom of the ship, we have to calculate the contact area of the bottom with water. If the contact area is too large, it may increase unnecessary resistance. If the contact area is too small, it may cause instability when the ship is sailing. Consequently, we calculated that the weight of the ship itself is 173 g, and then used this weight to test the ship's sinking depth and the contact area of the bottom with water to adjust the weight of the ship. (20150611.D.GG)	Technology, engineering and mathematics
Circuit and fan rotation were tested (20150613.D.GF) 	Technology and engineering
Problem: The wings are too small, causing the ship to be unbalanced and too slight. Solution: Straws are used to increase the water contact area, and clay is stuffed into the ship. (20150723.R.GF) 	Technology and engineering

... For long-term residence, the ship's vacuum wall can insulate against extreme temperatures. Additionally, the outer wall is also coated with nano-paint, which is not only waterproof but also dirt-proof and anti-rust. The ship's air-conditioning equipment allows the room temperature to be maintained within the range acceptable to humans. In addition, the solar panels can continue to supply power, and the excess power will be automatically stored in the battery as a preventive measure. Additionally, the streamlined hull and the air cushions equipped in the bottom of the ship bow can reduce wind resistance, increase buoyancy and build up speed... (20150616D.GA)

Students can overcome the limitations of existing technology and materials, reality and current time and space via imagination and by boldly envisioning and building the images of future ships. Imagination can transcend the existing technology and can apply knowledge by means of information collection and repeated thinking. In the process, students have the opportunity to explore higher levels of STEM knowledge and achieve the goals of learning.

The iSTEM learning model can facilitate the learning and application of integrated knowledge

It is concluded from the study that the process of imagination can expand the exploration and study of STEM knowledge. Turning imagination into images and pictures and then into efficient actual constructions is the ultimate task of this thematic activity. In the hands-on process, from electrical engineering, hull design, selection to model production, students repeatedly solve problems in the cycle of "discovery, hypothesis, test and correction" and learn to integrate and apply STEM knowledge. The integration and application of STEM knowledge are detailed in **Table 1**.

Analysis of iSTEM Learning Effectiveness

Analysis of iSTEM imagination ability

The iSTEM imagination ability questionnaire was divided into three dimensions including emotional motivations, psychological operation and concrete representation. A statistical analysis was carried out with one sample t-test, and the mean 3 was taken as the test value. The averages are more than 3.7, and reach the significant level of .001. This suggests that iSTEM learning produces a positive effect on the students' imagination ability.

With respect to emotional motivations (M=4.23~3.74, t=9.13~3.78, p<.001), students show positive willingness and emotions regarding iSTEM learning, which can effectively promote the willingness and motivation to get involved in imagination activities. For psychological operation (M=4.10~3.77, t=9.59~5.51, p<.001), the design and arrangement of activities allow students to make flexible use of exploration, initiation, development, alternative, links and other imagination techniques, hence helping to increase diverse mental images and thus producing more ideas and creating more logical connections and meanings. Finally, through the use of concrete representation (M=4.05~3.79, t=8.28~4.94, p<.001), students can build the imagined images or concepts into an imaginative and efficient ship by taking into account the existing technology, materials and costs.

Analysis of effectiveness of STEM integrated thinking and application ability

The STEM integrated thinking and application ability questionnaire consists of 5 dimensions including behavioral driving force, psychological operation, cognition, cooperative learning, hands-on and application. A statistical analysis was carried out with one sample t-test, and the mean 3 was taken as the test value. The averages are more than 3.8, and reach the significant level of .001. This suggests that iSTEM learning produces a positive effect on the students' integrated STEM thinking and application ability.

In terms of the behavioral driving force (M=4.15~3.97, t=10.75~6.74, p<.001), students can identify the value to themselves of iSTEM learning. As a result, they have a driving force to learn and are committed to participating in learning activities. Regarding psychological operation (M=4.10~3.82, t=8.74~5.79, p<.001), while performing tasks, students are able to carry out interdisciplinary integration, and in the face of problems, they can think about and analyze such problems from multiple views and put forward solutions. With regard to cognition (M=4.15~3.85, t=9.25~6.26, p<.001), after the activities, students' science, technology, engineering, mathematics and other cognitive abilities improved. For cooperative learning (M=4.18~3.97, t=9.74~6.97, p<.001), most of the students can develop social intelligence skills such as listening, respect, expression, acceptance and clarification. With respect to practice and application (M=4.13~4.00, t=8.80~6.60, p<.001), the practical exploration and construction proposed by iSTEM can more effectively promote knowledge learning and integration.

Analysis of effectiveness of the STEM knowledge ability test

According to the scores of the STEM knowledge pre- and post-tests of 39 students, there are significant differences in science (t(38)= - 2.72, p <.01), technology (t(38) = - 3.19, p <.01) and mathematics t(38) = - 4.67, p <.01) knowledge after iSTEM learning. The pretest results of science (M=2.28), technology (M=1.92) and mathematics (M=1.64) are significantly lower than the post-test results of science (M=2.85) technology (M=2.59) and mathematics (M=2.46). This illustrates that after the introduction of iSTEM learning, iSTEM learning can improve vocational high school students' learning effectiveness in science, technology and mathematics. The pre- and post-test scores for engineering (t(38)= - 1.51, p>.05) fail to reach the significant level, but the post-test score (M=3.15) is slightly higher than the pretest score (M=2.82).

These results demonstrate that iSTEM learning has a positive effect on students' STEM knowledge. It placed emphasis on the experiential learning model featured through learning-by-doing and encouraged students to explore and construct knowledge from hands-on practice, so there were plenty of opportunities to gain scientific and technological knowledge (Lou et al., 2011). Furthermore, according to the 2012 ability assessment and test results of international students, the mathematical and scientific performance of Taiwanese students is excellent internationally, which resulted from Taiwan's existing education system that attaches greater importance to science, mathematics and other disciplinary knowledge (Lin, 2014). Consequently, it can be estimated that if students have better performance in the original school education, they will have more satisfactory outcomes after an integrated experience and study using iSTEM learning.

RESEARCH CONCLUSION AND SUGGESTIONS

In the construction of the iSTEM ability indexes, a total of 20 iSTEM imagination ability indexes and 50 STEM integrated thinking and application ability indexes are constructed. Such construction is the result of expert opinions and consensuses and can be used as a reference for higher vocational colleges to promote and assess iSTEM education programs. The details of the third-level science, technology, engineering and mathematics in cognition of the STEM integrated thinking and application ability indexes are fine-tuned in the actual application, based on the design of the solar pneumatic ship activity theme, in order to meet the needs of the courses.

The iSTEM learning model is a student-centered independent learning model integrating imaginative education and STEM education. First, STEM topics relevant to students' life experiences are selected as the learning topics, and the connotations of the theme for STEM knowledge are analyzed and become basis for the activity design. The design of the model is divided into six task stages, exploration, initiation, development, alternative, links and presentation. Each task stage uses driving questions as the guide to exploration and problem solving in order to integrate the theory and hands-on practice and allow students to construct meaningful learning. Furthermore, the mixed cooperative learning strategy is adopted. Students can develop their own learning plans and independently acquire knowledge based on their learning needs and habits. Meanwhile, when cooperating and learning with peers, students can inspire each other's ideas and learn together and thus develop interpersonal intelligence skills such as listening, acceptance and respect.

According to the model's application and effectiveness assessment results, the iSTEM learning model can effectively enhance the acquisition and integration of STEM knowledge, stimulate imagination, and sharpen STEM integrated thinking and application ability. Imagination enables vocational high school students to transcend the limitations of existing conditions, boldly think about a myriad of possibilities and have the opportunity to explore more advanced STEM knowledge. Additionally, in the transformation of imagination and practice, students repeatedly apply the cycle of "discovery, hypothesis, test and correction" to solve problems, and learn to integrate and apply STEM knowledge. iSTEM provides a new direction and thinking for exploration-oriented STEM education and the integration of imagination. As a result, the study of engineering or life science and technology courses can be developed in a more diversified manner to encourage students to develop interests in engineering or technology programs and the consequent career orientations.

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