A Case Study on the Problem Representation of College Science Students in the Lego Building Process

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Abstract: The purpose of this study is to analyze the problem representation of college science students in the Lego Building Process. The present study selected fourteen college science students as participants. Using the thinking-aloud method and triangulation to collect materials, the study found that the selection tendency of problem representation, ranging from more to less, was action representation, image representation and symbolic representation. That is, there are significant differences in action representation and image representation between participants with Lego building experience and those without Lego building experience. There is no significant difference in the proportion of different problem representations between different types of tasks by gender or experience. Additionally, there is no significant difference in the selection tendency of problem representation between high building-capacity students and low building-capacity students, but there is a significant difference in the transformation rule of problem representation. This study provides some suggestions on teaching practices for college Lego education based on the results.

Keywords: Lego building, problem representation, transformation rule

1. Introduction

Lego education, drawing widespread attention, recently has been introduced into education systems in developed countries such as Britain, America, and Japan. Domestic studies on Lego Education largely focus on primary education (K12), but are lacking in higher education (Benitti, F. B. V., 2012;Xue Qingping, & Li Weihong, 2012). Studies on Lego Education in higher education primarily involve engineering courses and computer courses in universities (Danahy, E., Wang, E., Brockman, J., Carberry, A., hapiro, B., & Rogers, C. B., 2014; Foundation Coalition, 2001; McWhorter, W. I., 2008). Correct and effective problem representation is the key to solving problems (Moreno, R., Ozogul, G., & Reisslein, M., 2011). Studies on problem representation primarily focus on mathematics and physics in primary and secondary schools at present (Krawec, J., 2014; Orrantia, J., & Múñez, D., 2013), and on lack of practice in such disciplines (Chae, K. H., & Lee, G., 2011; Shai, O., 2003). Through a long observation of Lego building courses, we found that the building capability of college science students is not at a high level. Requirements for problem solving and a practical ability for self-discipline are higher for science students than for art students. This paper, aiming to study cases in which college science students build Lego, tries to ascertain the features of cases that involve hands-on activities and provides suggestions and a theoretical basis for Lego building courses in college. In addition, this paper summarizes the features of adults' problem representation to provide suggestions for problem solving. This study involves three problems as follows:

(1) During the Lego building process, what is the selection tendency of college science students' problem representation approaches?

(2) Is there a significant difference in college science students' selection tendency and proportion of problem representation approaches among different variables (gender and with experience of building Lego)?

(3) Is there a significant difference between students who have high (H) and low (L) building-capacity in selection tendency and transformation of problem representation approaches?

2. Literature Review

2.1 Problem Representation

Representation, an important concept in psychology, means the modes of presentation in the brain (Bruner, J. S., 1966). It is the central part of problem solving. The problem is half solved if you obtain correct representation (Simon, 1986). Due to different purposes and fields of research, researchers keep to different standards of classification of problem representation. Fu Xiaolan considered that problem representation is the process of finding problem structure and building problem structure to convert external physical stimuli to internal psychological symbols (Fu Xiaolan, & He Haidong, 1995). Problem representation is both a process, that is, the understanding and internalization of the problem and a result of problem understanding, that is, the problems presenting in the brain (Xu Xingchun, 2002). Boqin, Huang Xiting and Fan Wei classified the problem representation into four types: character representation, naive representation, physical representation and figure representation (Boqin, Huang Xiting, & Fan, 1997).

2.2 Methods of Problem Representation

Researchers adopt different methods when studying problem representation. Some researchers analyzed participants' types and features of problem representation by designing problem situations and observing the process of problem solving (Domin, D., & Bodner, G, 2012). Some researchers adopted interview and questionnaire methods (Stylianou, D. A., 2011;Krawec, J. L, 2014;Wang Libing, 2009), whereas some researchers adopted the content analysis method (Feng Meiling., 2003) or the Thinking-aloud method (Kammerer, Y., & Gerjets, P, 2013).

2.3 Related studies

Recently, Lego Education, drawing widespread attention, has been accepted into education systems in developed countries such as Britain, America, and Japan. Domestic research on Lego Education largely focuses on primary education (K12), but is lacking in higher education (Benitti, F.B.V., 2012; Xue Qingpin, &Li Weihong, 2012). Studies on Lego Education in higher education primarily involve in engineering courses and computer courses in universities (Danahy, E., Wang, E., Brockman, J., Carberry, A., hapiro, B., & Rogers, C. B., 2014; Foundation Coalition, 2001; McWhorter, W. I., 2008). McWhorter (2008) did a survey in a college computer programing course's lead-in course to study the effect of the activities relevant to using Lego Mindstorms on college students' learning motivation, learning strategy and students' master level to course objectives, but the results showed no effect on the three questions. Danahy (2014) studied the effect of Lego Mindstorms on the engineering courses of a university. The study concluded that Lego Mindstorms enabled students to reach higher accuracy without extensively learning circuit design and artificial intelligence. Currently, fewer studies are underway on Lego building problems representation.

Studies on problem representation largely focus on mathematics and physics in primary and secondary schools at present (Krawec, J., 2014; Orrantia, J., & Múñez, D., 2013). Krawec (2014) did a study on students with learning difficulties, low learning effect and average learning effect on problem representation solving math problems. In the field of hands-on practice, there are a few studies, primarily involving engineering design and drawing (Chae, K. H., & Lee, G., 2011; Shai, O., 2003). Problem representation in engineering design primarily focuses on the purpose of image representation that aims to discover the connection between knowledge from a system of math knowledge generated from engineering methods (Shai, O., 2003). Examples include analyzing an entire engineering system (Shai, O., & Rubin, D., 2004), designing an engineering system (Shai, O., 2003), finding a connection between engineering systems (Shai, O., 2001), and matching knowledge in an engineering system field with knowledge in other fields (v Shai, O., 2002). Chae (2011) studied problem representation in the field of drawing. The study compared the cartographic representation and drawing approaches of Korea and the United states and discussed how to improved cartographic representation and drawing approaches after introducing Building Information Model (BIM) into drawings. They found that the readability of a drawing is increased after removal of redundant information between drawings.

2.4 Brief summary

From the literature review, we found that different reasearchers have different concepts on problem represention due to different research views and aims. After analyzing those different concepts, this paper defined problem representation as the strategy adopted when an individual is understanding a task. We divided it into action representation, image representation and symbolic representation according to the classification of Brune. Action representation means an individual understands things by acting on them; image representation means an individual understands things by forming images; symbolic representation means an individual understands things by symbols, particularly via language (Bruner, J. S., 1966). With Lego building, action representation means an individual seeks building ideas by building; image representation means an individual forms images, situations or uses experience to build; symbolic representation means an individual understands a task requirement by retelling the task or identifying keywords of the task. Basing on the analysis of those studies on Lego and problem representation, we know that there are few studies on problem representation in the field. This paper adopted the Thinking-aloud method and Triangulation to analyze the college science students' approach to problem representation during the Lego building process and further analyzed adults' features of problem representation, hoping to giving advice and a theoretical basis for college Lego building courses and adult education to foster problem solving ability.

3. Design

3.1 Participants

This study selected fourteen college science students aged 22 to 24. We consider those students who have taken Lego building course experienced participants; these included three men and four women. We considered those students who had not taken Lego building courses inexperienced participants; these included four men and three women,. The males outnumber females by one, and students with Lego building experience outnumber those without Lego building experience by one.

3.2 Method

3.2.1 Thinking aloud method

Duncker and Lees (1945) first proposed the Thinking-aloud method, an important research method in the field of problem solving. At present, the Thinking-aloud method is primarily used to study problem representation during the process of web evaluation (Kammerer, Y., & Gerjets, P, 2013). The method's main feature is requiring participants to speak their thinking process aloud when they are doing the designed task; that is, they must report what they are thinking. Then, researchers analyze the oral report material to detect the thinking process and its problem and regulations.

3.2.2 Triangulation

Triangulation includes material triangulation, investigation triangulation, theory triangulation and methodology triangulation (Huang Youchu, 2014). Our study used material triangulation to obtain more-accurate information, thus ensuring validity. The Thinking-aloud method has some limitations; for example, it may affect the participant's thinking process because he or she must talk while thinking. Moreover, many scholars have questioned the integrity and facticity of data from the Thinking-aloud method because the thinking process is implicit (Hauge, C. H，2015). Therefore, our study performed questionnaire investigation and conducted an interview immediately after the participant finished the building task to obtain more information as complementary explanation to videos. Observation, questionnaire and interview form a triangulation.

3.3 Problem Representation Tasks

3.3.1 Tasks Set

In this study, the research team and educational technology experts identified two Lego building tasks according to difficulty level.

The first task is to build a "vertical clover fan" and is marked T1. T1 requires the Gear-driven blades to rotate rapidly while the fan stands steadily on the table. To increase the difficulty of building, certain aspects of building are specified in this study such as the height of the fan, the length of the blades, that the blades evenly distribute and so on. It takes approximately 50 minutes to finish T1. The building process is more difficult and relates to some physical knowledge including triangle stable structure and secondary transmission gear.

The second task is to build a "seesaw" and is marked T2. T2 requires that the seesaw maintains balance and stands steadily on the table in the natural state. To examine the application capacity of the subjects on the equipment, the length of various seesaw parts, the width of various seesaw parts, the number of blades and specific lengths of blades are required. It takes approximately 10 minutes to finish T2. The building process is less difficult and relates to some physical knowledge including triangle stable structure and the Lever principle.

3.3.2 Score Standard

The score standards were based on a mature score standard pattern which has been used by an instructor with rich experience in teaching the Lego Mindstorm course at the selected university for three years. Referring to her evaluation form, our score dimensions are given for three aspects including completeness, aesthetics and innovation.

3.4 Triangulation Tool

3.4.1 Coding Book

This study used two types of coding tables involving the various stages of the Lego building process and the type of problem representation. The first coding table, which aims at distinguishing between the various stages of the Lego building process, is based on the general problem settlement pattern proposed by M.L. Gick et al. (Gick, M.L., & Holyoak, K.J., 1980). It combines strong practical features of Lego building, all phases of the Lego building process are identified as understanding and characterizing tasks, trying to build, evaluate and others . The second coding table aimed at distinguishing the types of problem representation, divides the type of problem representation into action representation and image representation, symbolic representation and other representation mode according to Jerome Seymour Bruner's division of representation (Bruner, JS, 1966).

3.4.2 Questionnaire

To supplement the content of video observation, this study further deigned the questionnaire to immediately followthe subjects' completion of the building tasks. It primarily aims at learning subjects' selection tendency toward representation and order of representation in the building process.

3.4.3 Interview Table

The interview table was used after the coding was finished. Interview subjects were questioned to understand the specific thought processes within the time slice in which coders were uncertain in the coding process. Coding tables, questionnaires and interview table form the triangulation tools.

3.5 Pilot Study

Two experts recognized the coding tables. After ensuring validity of the coding tables, two subjects with no Lego building experience were tested in the pilot study before the formal study to ensure a feasible study, test task difficulty, set the time to build and modify the coding table. After the pilot study, researchers selected T1 and T2, which are more in line with the level of subjects from six candidate tasks, and substantially determined that the building times of T1 and T2 were 50 minutes and 10 minutes respectively. Then, two coders made a pre-coding that pauses 10s once based on a 40-minute video selected from a 60-minute video of one of the subjects. Two coders' Kappa values of the two coding tables were 0.7211, 0.525 respectively, they were highly consistent and standards-compliant.

3.6 Materials Collection

3.6.1 Observation

Researchers stated the requirements of the tasks to the subjects, asked them to complete the tasks using the method of thinking aloud and recorded the entire building process and all speech of the subjects with a video recorder at the same time. The researchers would provide reminders or queries when the subjects appeared to pause for a long time during the thinking-aloud process, but tried not to interfere with their thinking processes.

3.6.2 Questionnaire

After the building tasks were finished, subjects were asked to complete the questionnaire, which covering subjects' selection tendency toward representation, order of representation and the design programs of tasks in the building processes of T1 and T2.

3.6.3 Interview

After coding, researchers summarized uncertain time slices in the coding process. Interview subjects were asked about their thought processes at those uncertain times to supplement data collection.

3.7 Materials Analysis

Researchers sorted out and input the coded data into spss20 to analyze them as follows. (1) Analyzed the proportion of students' various representations using a descriptive statistical analysis method. (2) Used a U-test to analyze whether there are significant differences between the representation of subjects who have Lego building experience and those who do not, and the representation of subjects in different types of tasks and whether there was a significant difference in the representation of different gender subjects. (3) Test scores were set up in descending order, taking the first 30% as high building-capacity students, marked H, and the last 30% as low building-capacity students, marked L. Researchers analyzed whether there were significant differences in problem representation and transformation of problem representation of high building-capacity students and low building-capacity students using the U-test analysis method.

4. Results and Discussions

4.1 Results

4.1.1 Selection tendency toward the types of problem representation

Figure 1 shows that the proportion of various types of problem representation is different in the Lego building process. Among the four types of problem representation, the action representation is 73%, the image representation is 15%, the symbolic representation is 9% and the other representation is 3%. The percentage of the action representation is highest in the Lego building process.

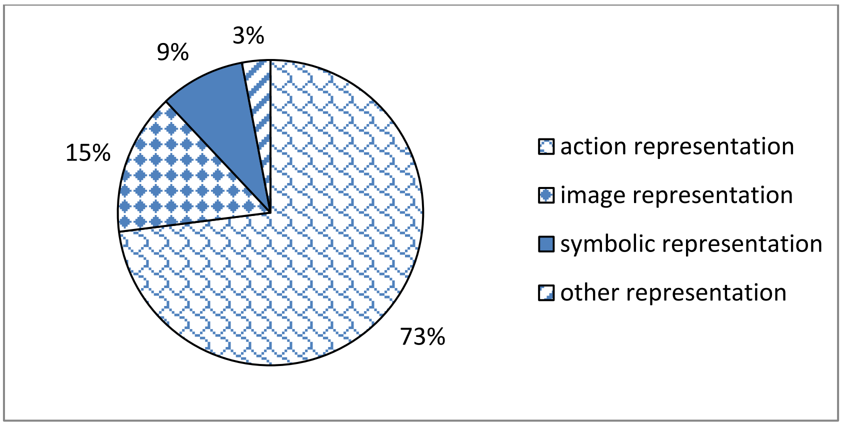

Figure1: The proportion of each Representation

4.1.2 Analysis of the selection tendency and the time proportion

Table 1: The analysis of the selection tendency toward representation (Mean)

		Action Representation	Image Representation	Symbolic Representation
Task Type	Task1	0.79	0.11	0.08
	Task2	0.67	0.19	0.10
Gender	Male	0.71	0.18	0.10
	Female	0.75	0.13	0.08
Experience	Experienced	0.61	0.24	0.12
	Inexperienced	0.85	0.06	0.06

Table 2: The U-test of Task Type, Gender and Experience

		Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-sided)
Task Type	Action Representation	57	135	-0.87	0.386
	Image Representation	52.5	130.5	-1.13	0.260
	Symbolic Representation	70	148	-0.12	0.908

Gender	Action Representation	66	144	-0.35	0.729
	Image Representation	63.5	141.5	-0.49	0.623
	Symbolic Representation	72	150	0.00	1.000
Experience	Action Representation	28	106	-2.54	0.011
	Image Representation	23.5	101.5	-2.80	0.005
	Symbolic Representation	30.5	108.5	-2.40	0.017

Table 3: The analysis of time scale of representation

			Time scale of representation	
			M	SD
Task 1	Experience	Experienced	0.35	0.09
		Inexperienced	0.28	0.11
	Gender	Male	0.33	0.07
		Female	0.31	0.13
Task 2	Experience	Experienced	0.32	0.14
		Inexperienced	0.25	0.11
	Gender	Male	0.27	0.15
		Female	0.30	0.11

Table 4: The U-test of Experience and Gender in different type of tasks

		Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-sided)
Task1	Experience	14	35	-0.64	0.522
	Gender	14	35	-0.64	0.522
Task2	Experience	12	33	-0.96	0.337
	Gender	15	36	-0.48	0.631

As seen in Tables 1, 2, 3 and 4,there is no significant selection tendency difference between the action representation ($Z = -0.87$, $p>0.05$), image representation ($Z = -1.13$, $p>0.05$) and symbolic representation ($Z = -0.12$, $p>0.05$) in different tasks. In different tasks, different gender subjects showed no significant differences in the tendency toward selection of the representation and the time proportion. In the T1 and T2 tasks, subjects who had Lego building experience showed similar time proportion for the presentation, while showing significant differences in the selection tendency of the action representation and the image representation.

4.1.3 Analysis of the types of representation selection and transformation of high (L) and low (L) building-capacity students

Table 5: The tendency toward representation selection of high and low building-capacity students

	Action representation	Image representation	Symbolic

						representation	
		(M,SD)		(M,SD)		(M,SD)	
Task1	H	0.72	0.19	0.20	0.18	0.05	0.03
	L	0.81	0.08	0.05	0.05	0.12	0.13
Task2	H	0.52	0.30	0.31	0.27	0.13	0.09
	L	0.83	0.07	0.08	0.08	0.04	0.03

Table 6: The U-test of the type of representation in different tasks

		Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-sided)
Task1	Action Representation	6	16	-0.58	0.564
	Image Representation	3.5	13.5	-1.32	0.189
	Symbolic Representation	5	15	-0.87	0.386
Task2	Action Representation	3	13	-1.44	0.149
	Image Representation	3	13	-1.44	0.149
	Symbolic Representation	3	13	-1.44	0.149

As shown in Tables 5 and 6, in T1, the tendency toward selecting action representation (Z = -0.58, p>0.05), image representation (Z = -1.32, p>0.05) and symbolic representation (Z = -0.87, p>0.05) of the high building-capacity (H) and low building-capacity (L) students suggested no significant difference. Additionally, in T2, there is no significant difference in choices of the high building-capacity (H) and low building-capacity (L) students among action representation (Z = -1.44,p>0.05), image representation (Z = -1.44, p>0.05) and symbolic representation (Z = -1.44, p>0.05).

4.1.4 Analysis of the transformation of problem representation of high (H) and low (L) building-capacity students

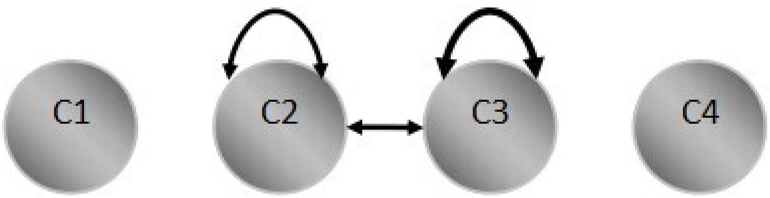

Figure 2 ：The transformation of high（H）building capacity students' problem representation

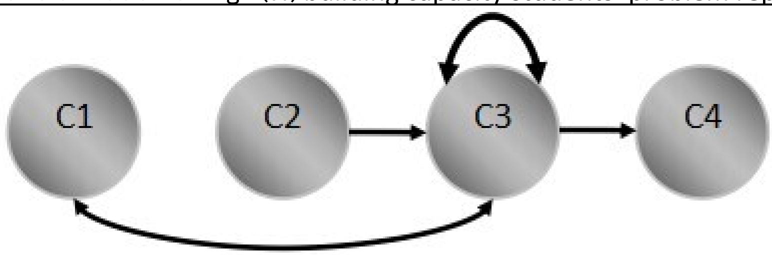

Figure 3 : The transformation of low (L) building capacity students' problem representation

This study further counted the transformation of the problem representation that the high building-capacity students (H) and low building-capacity (L) students made in T1 and T2 during the Lego building process. The researchers obtained C1, C2, C3, C4 and the transformation scale in and between each other (C1 on behalf of symbolic representation, C2 on behalf of image representation, C3 on behalf of action representation and C4 on behalf of others). They then finally selected the four high scales to draw the figure of the transformation of the problem representation (Hou, H. T., 2012). The study found that both the high building-capacity students (H) and low building-capacity (L) students showed similar transformation characteristics in different tasks. The transformation of high (H) and low (L) building-capacity students' problem representation is shown in Figures 2 and 3. The figure suggests that the majority of the transformation is the action representation internal transformation, which is the similarity of high (H) and low (L) building-capacity students, and the proportions are 60% and 74%. Moreover, concerning high building-capacity (H) students, the internal transformation of C2 and the transformation between C2 and C3 are a significant share. There are many transformations betweenC1and C3, and C3 to C4 with regard to low building-capacity students.

4.2 Discussions

Previous studies suggested that people can make a direct explanation with representation, then affect the process of their deduction (diSessa,1993).Various means of representation have close relationships with the solutions of the problems (Kohl, Rosengrant, & Finkelstein, 2007). Based on the data analysis, the study suggested that students preferred to choose action representation at first, then image representation, and symbolic representation at last when building Legos. However, in language learning, people were more willing to adopt the image representation generally (Orrantia, J., & Múñez, D., 2013), which was different from this study. With Triangulation, we found that action representation generally was used to determine whether the tools chosen were suitable, whether the steps adopted were good, whether the work was perfect and so on by the students. Moreover, students used image representation to form a static image or dynamic situation about the tasks in their brains. Students also could combine their previous Lego building experience, such as the characteristics of all the tools, with their life experience, such as previous knowledge that the obvious characteristic of a triangle is that it is stable, to finish the tasks. Some students repeated the key words of the tasks though symbolic representation.

By analyzing the time scale of the problem representation in different types of tasks, we found that there was no significant difference; namely, whether the task is difficult or easy, the time proportion of the problem proportion is similar, indicating that with certain time proportions of representation, the task can be complete successfully. In the process of solving a problem, the process of representation is the process of transforming information, which affects problem-solving (Vessey,2006), and representation plays an important role in the process of problem-solving (see, e.g., de Jong &Ferguson-Hessler, 1996). In the study of adult representation, Chen et al. (2006) found that there was no significant gender and age difference in the level of problem representation, and adult problem representation is stable. In the process of Lego building, there was no significant gender difference in the tendency toward selecting different types of problem representation, and the tendency of subjects toward selecting various types of representation is action representation, image representation and symbolic representation in descending order. In tennis, experts can create more integrated, diverse and complex conditions and actions than novices can (McPherson, S. L., 1999). Similarly, in the process of Lego building, there exist significant differences in the selection of action representation, image representation and symbolic representation by experienced and inexperienced students. Compared with experienced students, inexperienced students used more action representation and less image representation and symbolic representation. Reasons for this difference may be that inexperienced students were unfamiliar with the function and the possible combination of the equipment; however, experienced students can use their previous experience to choose the appropriate equipment and make the correct combination. Inexperienced students needed to choose the right equipment and make right combination to achieve the desired tasks through several attempts that were parts of action representation.

Appropriate use of spatial representations can support reading, mathematics and science learning, spatial representations can also simulate psychological situation, realize visualization, to promote innovation and scientific discovery (Sawyer,R.K.,2005) .Therefore, the types of representation affect problem solving. Through Triangulation, this study found that the selection scale of image representation of the high building-capacity students (H) was significant higher than that of low building-capacity (L) students, which suggested that the high building-capacity students (H) can better combine life and Lego experience. As for the transformation of the problem representation, the similarities of high (H) and low building-capacity (L) students were that the majority of the transformation was the action representation internal transformation, which was consistent with the characteristics of Lego building requiring many equipment components to verify suitability. Previous studies suggested that experts can form the external and internal relationship of the problem, and can solve the problem in a forward-looking manner (Tua A. Björklund, 2013). In this study, the researchers found that high building-capacity (H) students can use image representation more effectively, use their previous experience to develop an overall understanding of the problem, and then guide their building; in other words, they can consider the entire assembly at the beginning of building. The low building-capacity (L) students can only focus their attention on part of the problem, completing the whole before making a part combination. Moreover, they always adjusted the tasks when they found defects or errors; therefore, there were many setbacks during their building. Some studies have shown that novices tend to work backward, whereas the expert tends to work forward based on the specific student (Larkin, McDermott, Simon, & Simon, 1980; Sweller, Mawer, & Ward, 1983). Additionally, this study suggested that high building-capacity (H) students can provide image representation meaningful feedback with the action representation inspecting the equipment to prompt the process of building. Low building-capacity (L) students cannot think meaningfully after action representation, but become dazed or stagnant.

5. Conclusions

5.1 Conclusions and Suggestions

Correct and appropriate problem representation plays a very important role in the successful resolution of the problem. This study provided appropriate advice and inspiration for hands-on courses based on analyzing and discussing the features of science students' problem representation in the process of Lego building. First, individuals tend to use action representation and image representation to finish the tasks in the case of solving hands-on problems. Therefore, Teachers should encourage students to form an effective action representation through several attempts and develop possible solutions by combining the effective representation with their specific living and learning experience. The integrated use of a variety of problem representations is very important for the successful resolution of problems (Kohl, Rosengrant, & Finkelstein, 2007). In the teaching process, teachers should encourage students using a variety of methods to solve the problems from multiple angles.

When a problem representation cannot solve the problem effectively, one can change it or use a variety of representations to think about and then resolve the problem. Therefore, students should focus on expanding and enriching their own knowledge and experience in daily life. If teachers in the teaching process find and hold in reserve an effective solution to a particular problem students lack experience to solve, the teachers can provide it as a certain degree of knowledge supplement to enable the students to solve the problem successfully. Meanwhile, teachers can provide students a certain degree of knowledge supplement to enable them to solve a particular problem successfully if they find that students lack the experience necessary for an effective solution to the problem in the teaching process. Next, the problem representations of individuals functioning as part of a team and acting as individuals are different; the former are more abstract (Schwartz, 1995). Therefore, complex hands-on activities are more suitable for the teamwork form. The advantages are that complementary capabilities of students can better promote the completion of the task. Finally, in the adult stage, the level of problem representation does not change significantly with increased age (Bo Chen and JiLiang Shen, 2006). Therefore, cultivating an individual's problem-solving skills through hands-on must start early. In addition to teaching declarative knowledge in the teaching process, teachers should also create more opportunities for students to learn hands-on to form a deep understanding of knowledge.

5.2 Limitations

First, this is a small-sample study because of the small number of subjects. Therefore, the study is limited by the number of subjects. Second, the study lasted more than two months, a relatively short time that is not sufficient to follow students' problem representations in a different period. Furthermore, because different scholars' points and the content of their studies differ, the definition of the concept of problem representation is divergent; it is not yet a unified understanding in the academic world.

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