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Abilities analysis of problem-solving process awareness for elementary school students with different problem-solving performances

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Abstract. Background: Awareness is core ability in problem-solving process, but related performance analysis of problem-solving process awareness for elementary school students is still under study. It is one of the research gaps. This research summarizes problem-solving process awareness dimensions of translation and implementation to study. Former includes recognition and representation, and latter includes strategy and execution, review and check. Objective: According to the results of the literature analysis and research gap, this study aims to explore the problem-solving process awareness ability for elementary school students with different problem-solving performances by utilizing related instruments. Method: This research utilized two instruments of problem-solving process awareness and problem-solving to assess process awareness and problem-solving performances each for elementary school students. There were 389 elementary school students in Chiayi of Taiwan were selected by using stratified and cluster sampling to collect and analyze data. The single-factor multivariate mean test and η^2 effect size value, Roy-Bargman step-down F test and simultaneous confidence interval test were carried out. The analysis above which was conducted by SPSS for Windows. Result and conclusion: It is found that there were significant differences in performances of problem-solving process awareness for students with different problem-solving abilities after adequate data analysis. The performances are considerably different in translation and implementation awareness for students with differing word problem solving ability that translation awareness included recognition and representation awareness, and implementation awareness included strategy and execution, review and check awareness. So, conclusion is listed as follows. It is that students with different problem-solving performances have real differences in translation, implementation and overall awareness of problem-solving process corresponding to research problem.

Keywords. Process awareness in problem-solving, elementary school students, learning.

1. Introduction

1.1. Importance of awareness in problem-solving process and research theme

From the perspective of different model such as three problem-solving process skill-level model proposed by Demitra and Sarjoko [6], STAR problem-solving process strategy model proposed by Peltier and Vannest [25, 26], and self-regulation strategy development problem-solving based on STAR model proposed by Mulcahy et al. [22], it can be found that the various model stages and process model frameworks mentioned by the aforementioned scholars are all related to Polya [27] proposed four-stage problem-solving process model, and involve cognitive and metacognitive ability operation, and the high-level mental role played by metacognitive ability in the problem-solving process is the focus of scholars' research.

According to viewpoint of Adinda et al. [2], Cihanoglu [5], Yorulmaz et al. [35], the core source of metacognitive ability comes from the individual's awareness. Besides, researchers have found that the individual's metacognitive awareness has an impact on individual learning performance [1, 2, 4-6, 10, 35]. Moreover, it is even more believed that the metacognitive awareness ability of the individual has an impact on the performance of the individual in solving mathematical problems [1-4, 13, 14, 18, 24, 30, 32, 35].

Especially in the field of problem-solving, many scholars have found that no matter from viewpoint of self-promoting problem-solving ability proficiency learning development, or viewpoint of problem-solving strategy teaching improves problem-solving learning performance, setting metacognitive awareness ability in problem-solving has great effect on promoting individual problem-solving ability [4, 9, 11, 16, 17, 19, 22]. The development of metacognitive awareness proficient learning and the improvement of problem-solving learning performance have a key impact, which can not only promote the proficient learning and development of individual problem-solving ability, but also improve problem-solving learning performance [20, 22, 23, 25, 26, 31, 34]. Therefore, this study hopes to analyze the high-level meta-ability awareness operation and problem-solving performances simultaneously for elementary school students during the problem-solving process.

Integrating the research findings of the aforementioned scholars, the awareness of the problem-solving process can be roughly divided into four awareness sub-stages: problem recognition, representation, strategy and execution, review and check awareness. According to their nature, and the former two can be further integrated into two stages: translate awareness and the latter two integrated into implementation awareness, under the framework of the four sub-stages and two stages process, the individual awareness of the operation status of the aforementioned problem-solving process performances is explored.

1.2. Research gap, purpose and problem

At present, some researchers have researched to awareness in the problem-solving process with the awareness ability as the core. However, according to the results of the above-mentioned literature analysis, it is pointed out that awareness is indeed important and inseparable core ability in the problem-solving process. Therefore, to implement abilities analysis of problem-solving process awareness for elementary school students represent one of the research gaps.

Based on the above, this study aims to explore the problem-solving process awareness ability for elementary school students with different problem-solving performances by utilizing related instruments.

According to the aforementioned purpose, the specific questions of this research can be listed as follows. What are the abilities of problem-solving process awareness for elementary school students with different problem-solving performances?

2. Method

2.1. Participants

Because the elementary school curriculum is implemented in the form of one guideline and multiple textbooks in Taiwan, Kangxuan version is major, and Hanlin and Nanyi version is minor in Taiwan textbook market [12]. In order to facilitate the unification of the teaching textbook version, coordinate the teaching progress of the unit, and worry about the homogeneity of participants' problem-solving learning experiences in school, the stratified and cluster sampling are adopted for use to select the second-graders of ordinary classes in elementary schools in Chiayi County and City of Taiwan, the required samples were selected with the school as the cluster unit.

In the end, the actual number of students sampled was 10 classes from six schools in Chiayi County, 120 students from 5 classes from three schools in Kangxuan version (30.85%), 105 students from 5 classes from three schools in Hanlin and Nanyi version (26.99%), the total are 225 students (57.84%). Another total of 164 students were selected from 7 classes of four schools in Chiayi City (42.16%), 83 students from 4 classes of two schools in Kangxuan version (21.34%), 81 students from 3 classes of two schools in Hanlin and Nanyi version (20.82%), totaling 389 students (because there are no missing values, all are available and valid samples).

2.2. Instruments

2.2.1. Elementary school students' problem-solving process awareness scale (referred to as the problem-solving process awareness scale, PSPAS)

It integrates the analytical dimension and meaning of each scholar's awareness of the problem-solving process mentioned in the introduction as the basis for compiling, and then composes the item content with the problem-solving situation. It is divided into two dimensions contained translation and implementation awareness, four facets contained recognition awareness, representation awareness, strategy and execution awareness, review and check awareness.

According to the suggestion of the class teacher, on the item scale, use the five-point Likert-type scale of "know, often, sometimes, rarely, and don't know" (4, 3, 2, 1, 0) as the 16 items' assessment scale, using four problem-solving experts reviewed and corrected to support content validity. Exploratory and confirmatory factor analysis found above-mentioned factor structure, and extraction variation ratio and model fit were good (88.458% and 85.57%, AGFI = .995, NFI = .982, PNFI = .559). The α coefficient and composite reliability, extreme group's t-test of different item and scale, and the correlation between item and scale were also good (α = .954, CR = .9801, highest t = 52.204 and r = .873).

2.2.2. Single-step and two-step addition and subtraction word problems mixed problem-solving assessment (referred to as problem-solving assessment)

Refer to the semantic schema classification viewpoint of Fennell and Speer [7], Fuson [8], Morin et al. [21], Peltier and Vannest [25], Powell [28], Verschaffel et al. [33] for addition and subtraction word problem, it is compiled by analyzing its related problem-types in the single-step and two-step addition and subtraction word problems. The two-step will increase the number of problem-solving step combinations based on the single-step addition and subtraction method. In terms of single-step, it is divided into combine type, change type, and comparison type. The two-step aspect is divided into twice combine type, twice change type, one combination type and one change type, one change type and one combine type.

Points can be given for the operation procedures and the answer partial scoring. The maximum points for each question of single-step and two-step are two points and four points respectively, each with 4 items. The method of content validity is established same with the previous instrument. After the pre-examination of 110 non-sampled second-graders using the above-mentioned textbooks, the exploratory factor analysis shows that the factor structure is consistent with the compilation structure, and the eigenvalue of the oblique rotation are all greater than 1 (single-step

2.231, 2.110, 1.888, 1.766; two-step is 4.449, 4.467, 2.992, 2.654), 1.766 to 4.449, and the estimated explained variation ratio before the rotation is 8.942% to 32.440% (single-step 32.440, 25.867, 20.452, 13.382%; two-step 31.675, 26.367, 15.399, 8.942 %) have a considerable proportion (92.140% and 82.383% in total). In addition, it has good criterion-related validity, and its coefficients are .808 and .793 respectively based on the teacher's marking scores of the individual's single-step and two-step problem-solving unit classroom assignments after the single-step and two-step problem-solving unit teaching. Both the single item and the overall assessment *t*-test reached a significant level of .05 showing good discrimination, the single-step and two-step *t* values ranged from 3.516 to 68.474 and 3.948 to 47.466, respectively. The single-step and two-step internal consistency alpha coefficients were .886 and .813, respectively, indicating good reliability.

2.3. Design and Implementation procedures

This research had collected the performances of high-level meta-ability awareness operation and problem-solving abilities simultaneously for elementary school students during the problem-solving process. In order to achieve the purpose of activating problem-solving experience and collecting problem-solving performance, it will be implemented with problem-solving assessment. Problem-solving assessment be implemented first, problem-solving process awareness scale be implemented next. After that, data was analyzed. All of the above are carried out after obtaining the consent of the principal, director, teacher, parents and students.

2.4. Data analysis

For research problem, the single-factor multivariate mean test and η^2 effect size value, Roy-Bargman step-down *F* test and simultaneous confidence interval test were carried out. The analysis above which was conducted by SPSS for Windows.

3. Result and Discussion

3.1. Analysis of the actual measurement result of problem-solving process awareness ability for students with different problem-solving performances

The problem-solving assessment of the overall average performance of the top 27% and the bottom 27% of students ($N1GH$ = 109; $N1GL$ = 159) are group independent variables, problem-solving process awareness dimensions and facets are ability dependent variables.

The Wilks' Λ values of the multivariate test results representing those students with different problem-solving performances were different in awareness dimensions and facets of problem-solving process. There are differences in the subscale and overall ability.

As a result of the univariate test, which means that after probability correction, there are differences between students with different problem-solving performances in the subscale of translation problem-solving process awareness and in the awareness ability of recognition, representation, and strategy and execution facet. Both the high problem-solving performance group is better than the low problem-solving performance group.

The Roy-Bargman step-down *F* test was carried out. It means that after excluding variable overlapping variation, the independent variable has an impact on the dependent variable, that is, there are indeed differences in the translation and implementation awareness subscales, and recognize, review and check awareness facets of the problem-solving process for students with different problem-solving performance, that is, different problem-solving performances have an impact on the subscales of translation and implementation and the facets of problem recognition, review and check of problem-solving process awareness.

Therefore, it can be confirmed that there were real differences in awareness ability across subscales and partial facets of students with different problem-solving performances (the high problem-solving performance group outperformed the low problem-solving performance group, as seen by their means). The above analysis is shown in tables 7 and 8.

Table 7. Independent sample single-factor multivariate analysis of problem-solving process awareness subscales in individuals with different problem-solving performances

Independent Variable: PS	Dependent	Variables: TA, IA	
Items	TA, IA	TA	IA
Multivariate Wilk's Λ *F* and η^2	.877; 18.500 (p = .000) F(2, 265) η^2 = .123		
Univariate *F* and η^2		22.735 (p = .000); F(1, 266) η^2 = .079	3.447 (p = .064); F(1, 266) η^2 = .013
Group comparison		High >low	High >low

(*M*) (*SD*)		(28.734 > 24.610) (6.937; 6.967)	(27.835 > 26.006) (7.931; 7.914)
Step-down *F* *F*		TA 22.735 (p = .000); F(1, 266)	IA of exclude TA 13.220 (p = .000); F(1, 265)

Note. The values of the above items are all p = .000, p < .05. PS represents group of different problem-solving performances, TA represents translation awareness, IA represents implementation awareness.

Table 8. Independent sample single-factor multivariate analysis of problem-solving process awareness facets in individuals with different problem-solving performances

Independent Variable: PS	Dependent	Variables:	RGA, RPA,	SEA, RCA	
Items	RGA, RPA, SEA, RCA	RGA	RPA	SEA	RCA
Multivariate Wilk's Λ F and η^2	.820; 14.416 (p = .000) F(4, 263) η^2 = .180				
Univariate F and η^2		34.792 (p = .000); F(1, 266) η^2 = .116	5.471 (p = .020); F(1, 266) η^2 = .020	4.893 (p = .028); F(1, 266) η^2 = .018	1.561 (p = .213); F(1, 266) η^2 = .006
Group comparison (*M*) (*SD*)		High >low (13.459> 10.352) (3.7082; 4.561)	High >low (15.275> 14.258) (3.385; 3.572)	High >low (13.440> 12.252) (4.281; 4.350)	High >low (14.395> 13.755) (4.005; 4.193)
Step-down *F* *F*		RGA 34.792 (p = .000); F(1, 266)	RPA of exclude RGA 2.336 (p = .128); F(1, 265)	SEA of exclude RGA, RPA 1.833 (p = .177); F(1, 264)	RCA of exclude RGA, RPA, SEA 16.159 (p = .000); F(1, 263)

Note. The values of the above items are all p = .000, p < .05. PS represents group of different problem-solving performances, RGA represents recognition awareness, RPA represents representation awareness, SEA represents strategy and execution awareness, and RCA represents review and check awareness.

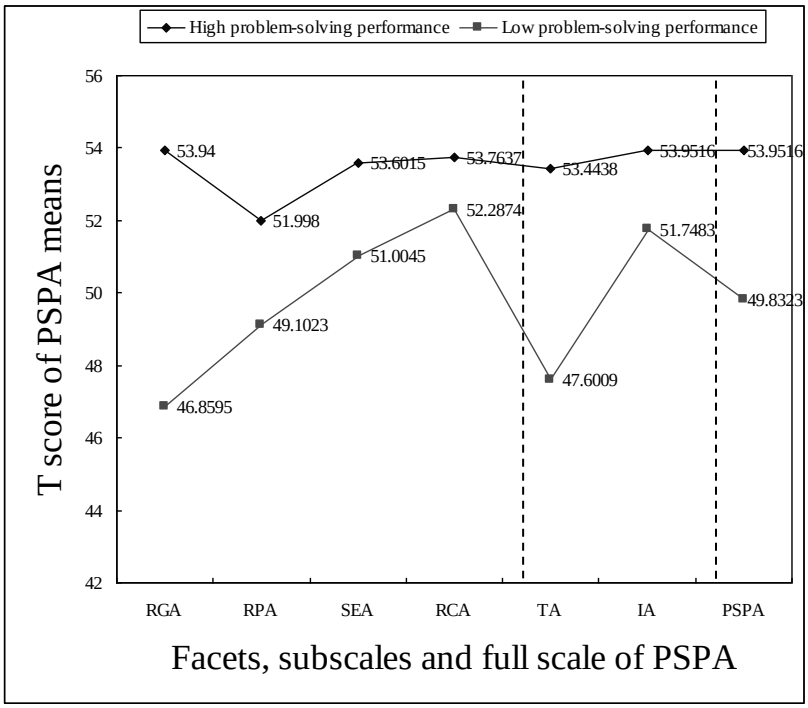

Figure 2. Profile of problem-solving process awareness subscales and facets' performances in individuals with different problem-solving performances (T score after linear conversion with reference to the means and standard deviation)

Note. RGA represents recognition awareness, RPA represents representation awareness, SEA represents strategy and execution awareness, and RCA represents review and check awareness. TA represents translation awareness, IA represents implementation awareness, and PSPA represents problem-solving process awareness.

The average raw scores of each awareness ability in each group is shown in table 7 to 8, and the common scale profile of T score after linear conversion with reference to the means and standard deviation data is shown in figure 2.

3.2. Comprehensive induction and concise discussion

Observing the results of the problem-solving process awareness and problem-solving measurement and analysis of students with different problem-solving performances, it was found that the univariate and multivariate step-down analysis results show that there are real differences in the two-dimension subscales and partial facets, that is, the basis of the significant differences are indeed from their respective contributions, regardless of the exclusion. However, their respective capabilities still have significant differences.

Therefore, students with different problem-solving performances have real differences in the subscales and partial facets of problem-solving process awareness, especially in the ability of students with different problem-solving performances in awareness of problem recognition and translation process has the largest gap, so problem recognition and translation process awareness may be the main reason that potentially affects students' different problem-solving performances. In terms of problem-solving performance, this also corresponds to Demitra and Sarjoko [6], Hastuti et al. [11], Montague et al. [20], Mulcahy et al. [22], Peltier and Vannest [25], Polya [27], Sagirli [29], Schurter [31], Wilson and Clarke [34] found. The research results of the connotation of translation and implementation awareness of problem-solving process, that is, problem-solving translation and implementation process awareness should have an impact on student problem-solving performance, which also provides better learning effectiveness for the problem-solving process awareness strategy teaching that integrates the former two the finding of a facilitation effect provided the underlying supporting evidence. In other words, if the problem-solving strategy teaching can be used to improve the awareness of student problem-solving process, it will have a positive impact on their learning performance. Therefore, it is necessary to integrate the problem-solving process awareness strategy into the teaching content, especially problem-solving translation process awareness strategies.

However, if researcher wants to improve or promote the awareness of student problem-solving process, researcher should not stop at the consideration of short-term teaching strategy intervention factors, but need to think from a broad perspective of student cognitive development. Therefore, the awareness of student problem-solving process long-term follow-up research is necessary.

In addition, based on the above inductive discussion, it can be seen that this study has achieved the goal of filling the research gap in the assessment and analysis of process awareness on the domain of problem-solving.

4. Conclusion and Suggestion

4.1. Conclusion

Based on the aforementioned results, conclusion is listed as follows. It is that students with different problem-solving performances have real differences in translation, implementation and overall awareness of problem-solving process corresponding to research problem.

4.2. Suggestion

Based on the aforementioned conclusion, suggestion is listed as follows. It can be found students with different problem-solving performances have real differences in translation, implementation and overall awareness of problem-solving process. So, follow-up research can focus on other important factors that affect student problem-solving learning, such as different grades, different problem-type such as mixed problem-type with many additions, subtractions, multiplications, and divisions, etc., and different learning contents such as graphic, area, volume, proportion, speed, etc. In addition, different sampling survey designs can be used to confirm the problem-solving process awareness of students with different problem-solving performances, and conduct developmental learning guidance research.

4.3. Research limitations

Although the results obtained so far in this study are all good, there are still some potential limitations. For reasons of the number of samples and sampling area are limited, so it is necessary to consider whether the research results are affected by sample-dependent factors, and it is not appropriate to apply excessive explanations and inferences to the problem-solving process awareness ability for all students in elementary school.

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