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The Effects of Multi-Modal Representations Used within the Context of Process-Based Instruction on Problem Solving, Academic Achievement, and Retention*

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Abstract

The purpose of the present study is to determine the effects of two multi-modal representations, the use of text and graph for learning, on problem solving, academic achievement and retention when used in a process-based instruction (PBI). The study was designed as quasi-experimental study complying with pretest-posttest control group design. The study group consists of (N=30+34=64) students from the department of classroom teacher education in the Education Faculty of a university from west of Turkey in 2015-2016 academic year. The data in the study were collected through problem solving inventory, texts written and graphs drawn by the students and academic achievement test. For the data analysis, independent-sample t-test, Kruskal Wallis H-Test and descriptive analysis techniques were used. According to the findings obtained in the present study, it can be argued that while there is no significant difference between the academic achievements and problem solving skills of the students carrying out their learning activities according to drawing-modal representation and those of the students carrying out their learning activities according to writing-modal representation, a significant difference in terms of their retention was observed.

Keywords: Process-based instruction, multi-modal representations, problem solving, academic achievement, retention.

Introduction

In recent years, many of the studies dealing with the efficiency of learning and teaching process focus on students' critical thinking skills (Herman, 2002; Stupnisky, Renaud, Daniels, Haynes, & Perry, 2008; Şendağ & Odabaşı, 2009), problem solving skills (Chan & Fong, 2011; Dochy, Segers, Van den Bossche, & Gijbels, 2003; Rodriguez-Fornells & Maydeu-Olivares, 2000), developing students' planning skills (Ashman & Conway, 1993), self-orientation and self-regulation skills (Bandura, 1991; Carver & Scheier, 1998; Schunk & Zimmerman, 1994). Especially as a result of continuous renewal of information, process-based approaches requiring process-oriented creative and critical thinking, problem solving and planning learning have been adopted more than product-oriented learning (Connell & Seville, 2009; Duman, 2008). In the present study, the emphasis is put on multi-modal representations used by students carrying out their learning activities based on process-based instruction.

Process-Based Instruction (PBI)

The conceptual framework of process-based instruction (PBI) has been created from the findings of neuropsychology, planning, problem solving and cognitive psychology research and educational and psychological research looking at the educational models aiming to develop specific information and thinking strategies and planning the educational process by raising students' cognitive awareness (Ashman & Conway, 1993; Duman, 2008; Vermunt, 1995; Wong, 1992). The purpose of PBI is to facilitate independent-learning and teaching, promote being creative and problem solver and develop students' inquiry skills and competencies (Duman, 2008).

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PBI requires the use of cognitive and affective strategies to help students to construct their thinking and learning strategies, raise their awareness of the process, gain information and skills needed to plan the process in different programs. According to Ashman, Conway and Wright (1994), PBI is a kind of process where students from various levels of schooling are encouraged to develop their thinking skills while carrying out learning activities under the guidance of the teacher (Duman, 2008). The steps of process-based teaching-learning model are: i. Introduction, ii. Establishment, iii. Consolidation, iv. Incorporation.

According to Knowless (1984), PBI is made up of seven elements: establishment of setting, carrying out mutual planning, determination of needs, setting learning goals, design of learning plans, application of learning plans, and evaluation of learning. PBI model represents a systematic learning-teaching approach that can be used by students to improve their skills for planning learning and problem solving. Hence, all students can make use of process-based approach as a cognitive awareness–based study strategy or method to enhance their cognitive, affective and behavioral states (Duman, 2004).

During PBI, students are taught to plan what to learn and how. Barker (1989) states that process-design approach enables students to carry out contextual analyses of concepts and phenomena within the framework of multi-thinking rules from enhanced viewpoints. In such learning-teaching environments, information is constructed by the cognitive activities of the learner. Learners learn how and where to learn which information by developing their own strategies and plans. In learning-teaching processes, various strategies, methods and tools and equipments are used to improve students' problem solving, individual study, cooperative learning skills etc. in a constructivist and effective environment. One of these tools is different modal representations for learning purposes.

Learning-Aimed Multi-Modal Representations

Multi-modal representations are learning-teaching tools facilitating to learn and reifying the abstract concepts in line with the natural functioning of the mind to contribute to students' efforts made to achieve learning goals relating students' knowledge, skills and attitudes. According to Prain and Waldrip (2006), "multi-dimensional learning" means not only showing students how they perceive in different ways but also practice what they have understood by presenting them through different modes such as textual, graphical and mathematical. The purpose of learning-aimed text writing prepared in compliance with multi-modal representations is to reach come certain conclusions and generalizations by writing about the topics and concepts studied and consolidate the learning by using various writing genres such as text, scenario, story, composition etc.

The usage of multi-modal representations has different ways of applications and research results. According to Andersen and Munksby (2018) research in using representations for teaching and learning in science reveals that transforming representations and producing multi-modal representations can strengthen students' potential for learning concepts. Hoban and Nielsen (2011) state that meaning making by creating representations may be enhanced when students create more than one representation of a concept. In science education, multi-modal representations can be used as a language of science. According to Tang, Delgado, and Birr Moje (2014) representations are artifacts that symbolize an idea or concept in science (e.g., force, energy, chemical bonding) and can take the form of analogies, verbal explanations, written texts, diagrams, graphs, and simulations. Studies show us that multi-modal representations are related with developing scientific literacy. Van Rooy (2012) and Van Rooy and Chan (2017) state that new ways of representing and communicating scientific concepts in classroom practice necessitate new forms of assessment, which may be used to evaluate student competencies across the range of modalities and multiple representations that students are now expected to be conversant with in becoming scientifically literate. Another research about multi-modal representations Tang and Birr Moje (2010) stress that each of studies makes an important contribution to knowledge in the study of multimodality in science teaching and learning.

According to Rivard and Straw (2000), writing or symbolization is an important tool to convert the basic ideas embedded in information and make information coherent and cohesive. The purpose of learning-aimed graph drawing prepared according to multi-modal representations is to visualize what has been learned by symbolizing it and make learning permanent by using different graphical displays such as cartoon, flow chart, figure, table etc. Research based on PBI model used in learning-teaching processes (Ashman & Conway, 1993; Barker, 1989; Connell & Seville, 2009) has revealed that there is an improvement in students' learning level and their attitudes towards learning. It has also been reported that permanent learning is realized by students while performing activities through multi-modal representations in a multi-dimensional learning environment (Atila, Günel, & Büyükkasap, 2010; Günel, Atila, & Büyükkasap, 2009). In addition to these, variations resulting from rapidly developing technologies and increasing circulation of information also alter students' learning expectations and needs. Therefore, learning activities and tools and equipments which can help students to improve their planning skills and their creativity are needed. In this respect, use of multi-modal representations in a PBI environment by students as a tool enabling them to make free use of their own learning strategies is expected to both meet students' needs and enhance the efficiency of learning-teaching process. Hence, the main focus of the present study is this question *"Does the use of writing and drawing-modal representations have some effects on problem solving skills, academic achievement and retention?"*

Purpose of the Study

The purpose of the present study is to determine the effects of learning-aimed writing-modal and graphic-modal representations based on process-based instruction on problem solving skills, academic achievement and retention. For this purpose, responses to the following questions were sought:

1. Is there a significant difference between the posttest academic achievement scores of the group carrying out learning activities by writing texts and those of the group carrying out the learning activities by drawing graphs based on process-based instruction?

2. Is there a significant difference between the retention levels of the group carrying out learning activities by writing texts and those of the group carrying out the learning activities by drawing graphs based on process-based instruction?

3. Is there a significant difference among the retention levels of the students carrying out their learning activities by writing texts based on process-based instruction according to the classification of the texts?

4. Is there a significant difference among the retention levels of the students carrying out their learning activities by drawing graphs based on process-based instruction according to the classification of the graphs?

5. Is there a significant difference between the problem solving scores of the group carrying out learning activities by writing texts and those of the group carrying out the learning activities by drawing graphs based on process-based instruction?

Method

The present study in which the effects of learning-aimed writing-modal and graphic-modal representations based on process-based instruction on problem solving skills, academic achievement and retention are investigated is structured as a quasi-experimental study with pretest-posttest control group design. The study was carried out on pre-service teachers attending the department of classroom teacher education of the Education Faculty at a university from west of Turkey in 2015-2016 academic year. The experimental design of the study is presented in table 1.

Table 1. Study design

Control group	**Experimental group**
Giving information and instructions	Giving information and instructions
Pretests	Pretests
Teaching the topic of "Visual Design Elements" (Process-based instruction)	Teaching the topic of "Visual Design Elements" (Process-based instruction)
Writing "Learning-aimed texts designed with multi-modal representations "	Drawing "Learning-aimed graphs designed with multi-modal representations "
Collection and evaluation of the written texts	Collection and evaluation of the graphs drawn
Giving feedback on the written texts	Giving feedback on the graphs drawn
Posttests	Posttests
Retention tests	Retention tests

Study Group

The study group consists of day-time and evening-time students (N=30+34=64) attending the department of classroom teacher education of the Education Faculty at a university from west of Turkey in the spring term of 2015-2016 academic year. The study group was determined by using random sampling method. Out of the participants, 48% (31) are males and 52% (33) are females. According to the information elicited by the personal information form, it is seen that the students are with middle socioeconomic and cultural level. The mean age of the students is 20. Academic achievement test was administered as a pretest to academically match the students and the results of the t-test revealed that there is no significant difference between them (p=.862). In this respect, it was found that the participants are equal in relation to the pretest scores.

Data Collection Tools

In the present study, three different data collection tools were employed. First one is Instruction Technologies and Materials Design academic achievement test; the second one is problem solving inventory to elicit the scores for problem solving skills; and the third one is texts and graphs formed by the students for their own learning activities.

The first data collection tool, Instructional Technologies and Materials Design achievement test, is related to issues of "Visual Design Elements". In this test, there are 20 multiple-choice questions. For the content validity of this test, literature review was made, the items concerning visual design elements were constructed and after exposing them to the scrutiny of three experts in the field, the test was developed. In order to determine the reliability of the test, it was administered to 50 students having taken the same course in the previous year and KR-20 reliability coefficient was found to be .79. The test includes items relating to visual elements, verbal elements, interest and attention drawing elements and metacognitive items concerning structural form in the design and arrangements in designs. The second one is problem solving inventory developed by Heppner and Peterson in 1982 (Savaşır & Şahin, 1997) to determine students' self-perceptions of their own problem solving skills. This scale was then adapted to Turkish by Şahin et al (1993). This inventory consisting of 35 items is constructed in the form of six-point Likert type. For the whole of the inventory, Cronbach Alfa internal consistency coefficient was found to be .90 by the developers of the inventory. For each item, participants are asked to indicate the frequency of displaying the behaviors stated in each item. The six options given for each item are "I always behave in this manner", "I usually behave in this manner", "I often behave in this manner", "I sometimes behave in this manner", "I rarely behave in this manner", "I never behave in this manner" During the evaluation stage, three items were discarded, and the other items are scored ranging from 1 to 6. The limits of the total score range from 32 to 192. The higher the total score taken from the scale is, the lower the self-efficacy of the participant felt for his/her problem solving skills is.

The third one is the texts and graphs created by students for their own learning activities. The texts were classified as "descriptive, explicative and synthesizer" and the graphs were classified as *"basic graph-drawing, flow chart, and concept map"*. The students' modal representations were analyzed according to these classifications.

Data Analysis and Interpretation

As the sampling of the study consists of two groups, t-test is thought to be the appropriate analysis method for this study. Prior to the study, t-test was used to analyze the data obtained from the administration of subject-based teaching technologies and materials design achievement test as a pretest to determine the readiness level of the students. Following the completion of the study, the same test was administered again as a posttest. Again, t-test (independent-sample t-test) was employed to analyze the data obtained from the posttest. For the retention test, Kruskal Wallis H-Test analysis was performed because of classification of the texts of the control group. Values calculated for normality tests to determine the distribution of the data set: Shapiro-Wilk significance value Problem Solving Inventory for pre-tests .129; Academic Achievement for pre-tests .193; Problem Solving Inventory for post-tests .214; Academic Achievement for post-tests .198. In this case, the data is normally distributed.

Problem solving skills elicited through problem solving inventory were separately analyzed for the control group and the experimental group. The high scores taken by the students from problem solving inventory indicate that their problem solving skills are inadequate. In the same manner, the low scores taken from problem solving inventory indicate that the problem solving skills of the students are good.

After the administration of PBI to the first group students (control group), they were asked to write learning-aimed texts about the relevant subject and concepts by using multi-modal representations. These texts then were classified as *descriptive, explicative and synthesizer* and were analyzed by seeking the expert opinions.
In the same way, the second group students (experimental group) were administered PBI and then they were asked to perform free graph drawings about the subject and concepts studied. These data were then classified as basic graph-drawing, flow chart, and concept map and then an evaluation was carried out on the data in light of 3 experts' opinions. Two of these experts are from Curriculum and Instruction field and one is from Primary School Teacher Training. According to the common views of the researchers and the experts mentioned, it was decided how to classify both text and graphic description modes. Parallel to the above-given explanations and classifications, the data were analyzed through descriptive analysis technique.

Activities Carried Out During the Experimental Process

Prior to the application, information and instructions were given to the groups about various modal representations by the researchers and then the steps to be followed throughout the study were explained. Throughout the study, following steps were followed with both the experimental and control groups: *"i. administration of the pretest, ii. Teaching of the topic "Visual Design Elements" based on process-based instruction, iii. Getting students to prepare texts and graphs by using multi-modal representations, iv. Collection and evaluation of modal representations, v. Giving feedback on modal representations, vi. Application of the posttest, vii. Administration of the retention test."* Throughout the process-based instruction, learning-teaching activities were designed as presented in the following flow chart.

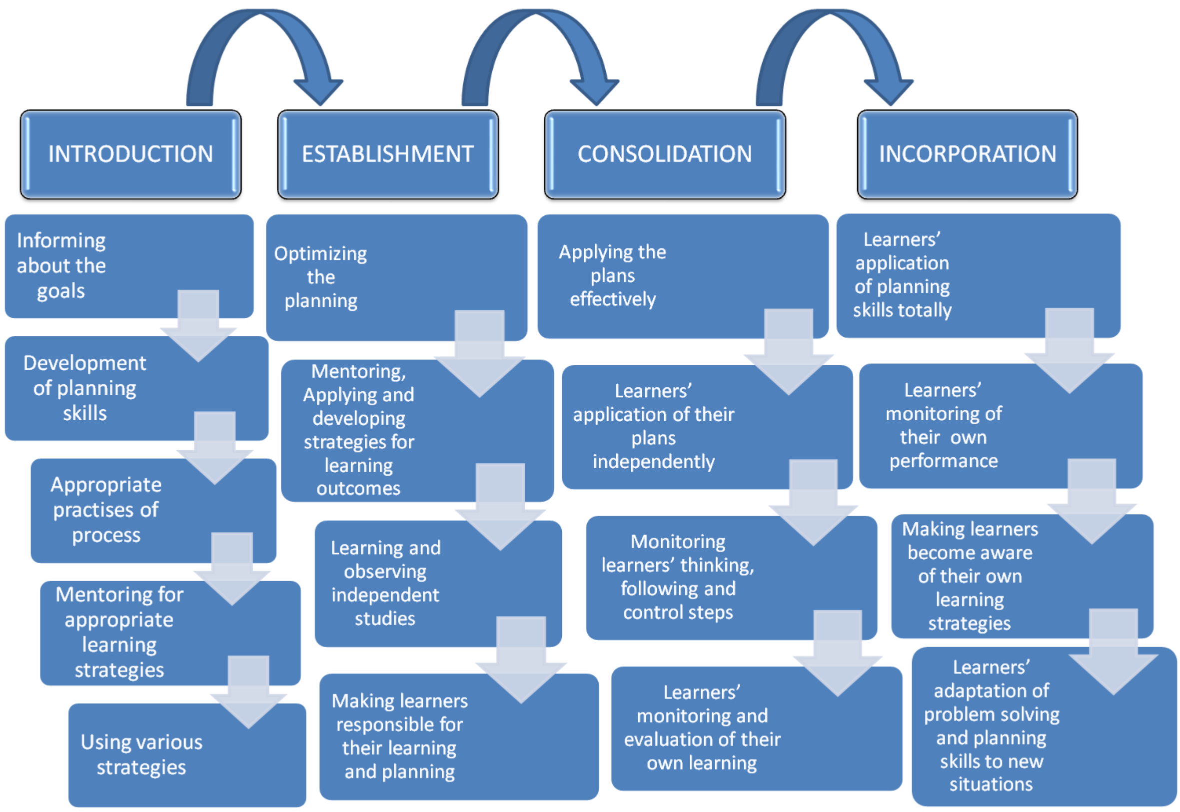

Figure 1. Flow chart of the process-based instruction

Introduction: First, the students were asked what the characteristic features of planning strategy, a pre-requisite for PBI, might be and discussions were conducted about them. Then, a general planning was made about Visual Design Elements; Visual – Verbal – Attractive Elements, Structural Form of Design and Arrangement of a Design and stages of the planning about the topic were applied.

Establishment: After making the necessary planning in the previous stage, orientation, application and acquisition strategies required by PBI were developed to establish learning activities about topic in the classroom. In accordance with these strategies, learning activities concerning the fact that visual design elements were divided into three as Visual – Verbal and Attractive elements and they were performed. The students were promoted to examine and correct the activities they carried out; in this way, they were encouraged to take the responsibility for their own learning. Various applications and activities planned were carried out in the groups formed. While conducting the activities within the groups, each student was also rendered responsible for his/her own works.

After consolidating the strategies used by the students in their individual and group works, some more activities were performed for the preparation of the presentation of materials during the consolidation stage to improve and direct the students' planning skills. This is because during the process, it was planned for students to develop materials to teach a topic.

Consolidation: What is expected to be done at this stage of PBI is to find out how materials related to visual design elements should be developed to teach a different topic selected based on a different planning. In this respect, monitoring and controlling strategies were employed in the planning of effective presentation. The students were provided with opportunities to monitor and evaluate the planning activities carried out by using above-mentioned strategies. In this way, the students' thinking patterns and planning strategies were directed. At the stage of incorporation, for the students to use what they learned and their planning strategies for further applications at different settings, applications such as summarizing, repetition, question-answer etc. were carried out.

Incorporation: The development stage of PBI requires planning skills to be administered to a new situation. It is expected that plans should be exactly implemented; students can follow their own performances and be aware of the process. Therefore, collaborative activities were performed to yield special planning samples for the structural form in the design. In this way, the students were allowed to overgeneralize their planning skills to different activities.
After teaching the lessons and subjects in line with this flow, the control and experimental groups were exposed to following applications.

The Activities carried out in the Experimental Group at the End of the Process:
Following the pretest and PBI applications, the experimental group students were asked to carry out one more application to evaluate the learning activities; and they were promoted to evaluate the activities by using graphs. Then, the students were given feedback on their graph drawing activities.

Activities carried out in the Control Group at the End of the Process:
Following the administration of the pretest and PBI, the control group students were asked to carry out one more application to evaluate the learning activities; and they were promoted to evaluate the activities by using learning-aimed written texts designed according to multi-modal representations. Then, these written texts were evaluated and the students were given feedback on them.

Findings

In this section, findings of the study are presented. First, arithmetic means of the scores taken by students from pretest, posttest, retention and problem solving skills tests are presented in table 2.

Table 2. Mean scores taken by the experimental and control group students from pretest, posttest, retention and problem solving skills tests

Groups	**N**	$\overline{X}$ **(Problem solving)**	$\overline{X}$ **(Pretest)**	$\overline{X}$ **(Posttest)**	$\overline{X}$ **(Retention)**
Experimental group *(Drawing graphs)*	34	131.7	14.6	17.6	18.7
Control group *(Writing texts)*	30	130.5	14.6	17.5	15.8

When the table 3 is examined, it is clear that the pretest arithmetic mean score of the experimental group is $\overline{X}$=14.6 and that of the control group is $\overline{X}$=14.6. The posttest arithmetic mean score of the experimental group is $\overline{X}$=17.6, and that of the control group is $\overline{X}$=17.5. Retention test arithmetic mean score of the experimental group is $\overline{X}$=18.7, and that of the control group is $\overline{X}$=15.8. T-test was conducted to determine whether there is a significant difference between the groups. Table 3 presents the results of t-test carried out to determine whether there is a significant difference between the posttest academic achievement scores of the experimental group and the control group [t(62)=.-321, p>.05].

Table 3. T-test analysis results of the posttest achievement scores of the experimental group and the control group

Groups	Posttest			
	$\overline{X}$	df	t	p
Experimental group *(Drawing graphs)*	17.6	62	-.321	.748
Control group *(Writing texts)*	17.5			

When table 3 is examined, no significant difference was found between the posttest achievement scores of the experimental group and the control group (p=.748). As a result of the application conducted in the present study, it can be argued that there is no significant difference between the groups in terms of their academic achievement scores. Then, t-test was conducted to determine whether there is a significant difference between the retention scores of the groups and the results of this test are presented in table 4.

Table 4. T-test analysis results of the retention scores of the experimental group and the control group

Groups	Retention			
	$\overline{X}$	df	t	p
Experimental group *(Drawing graphs)*	18.7	62	-3.502	.001
Control group *(Writing texts)*	15.8			

When table 4 is examined, it is seen that there is a significant difference in the retention levels of the groups favoring the experimental group carrying out learning activities by drawing graphs (p=.001). In addition to this, each group was classified into sub-groups based on the type of the writing or drawing. Within the control group, the students were classified into sub-groups depending on the type of the text and for each text type percentages and frequencies were calculated and presented in table 5.

Table 5. Classification of the learning-aimed texts written by the control group based on multi-modal representations and their percentages

Retention level	N	Descriptive		Explicative		Synthesizer		Total (%)
		N	(%)	N	(%)	N	(%)	
Medium *(15 or lower points)*	6	2	33	3	50	1	17	100
Good *(16-17-18 points)*	14	4	29	8	57	2	14	100
Very good *(19-20 points)*	10	0	0	4	40	6	60	100

When table 5 is examined, it is seen that 50% of the students having medium retention wrote explicative texts; 57% of the students having good retention wrote explicative texts. None of the students having very good retention was found to have written descriptive texts and majority of them (60%) wrote synthesizer texts which require higher level of competencies. The comparison of the control group students in relation to their posttest academic achievement and retention levels is presented in table 6.

Table 6. The comparison of the control group students in relation to their posttest academic achievement and retention levels

Retention level	N	Descriptive			Explicative			Synthesizer		
		N	$\overline{X}$ (Posttest)	$\overline{X}$ (Retention)	N	$\overline{X}$ (Posttest)	$\overline{X}$ (Retention)	N	$\overline{X}$ (Posttest)	$\overline{X}$ (Retention)
Medium *(15 or lower points)*	6	2	17.0	13.5	3	17.3	15.0	1	18.0	16.0
Good *(16-17-18 points)*	14	4	17.3	17.5	8	17.5	17.1	2	18.5	18.0
Very good *(19-20 points)*	10	0	-	-	4	18.5	20.0	6	18.8	19.2

When table 6 is examined, it is seen that the academic achievement level of the control group students having written descriptive texts and medium retention is lower than that of the students having good retention. Among the students having written descriptive texts, the ones having very good retention were found to have the highest academic achievement. Among the students having written synthesizer texts, the ones having medium retention were found to have lower academic achievement than the others. The table shows that parallel to the students' increasing level of academic achievement and their texts, their retention also increases. As can be seen in table 7, some retention scores are higher than academic achievement scores. This may be because the final exams by the students were taken at the same time when the retention test was administered. The retention scores of the control group students taken from the retention test in relation to the classification of their texts are presented in table 7.

Table 7. Kruskal Wallis H-Test analysis results of the students according to the classification of the texts of the control group

	Text types	N	Mean rank	df	x^2	p
Retention	**Descriptive Text**	4	9.00	2	7.72	.021
	Explicative Text	16	13.50			
	Synthesizer Text	10	21.30			
	Total	30				

According to within-groups text classification, the results of Kruskal Wallis H-Test analysis carried out for the groups carrying out their learning activities by writing texts reveals that there is a significant difference among the retention levels [x^2 (df=2, N=30) = 7.72, p<.05 p=.021] and in addition, there is a significant difference favoring the group writing synthesizer texts.

The experimental group students were classified depending on the types of the graphs they drew. The classification of the experimental group students' graphs and their percentages and frequencies are presented in table 8.

Table 8. Classification of the graphs drawn by the experimental group students and their percentages

Retention level	N	Basic-graphs drawing		Flow chart		Concept map		Total (%)
		N	(%)	N	(%)	N	(%)	
Medium *(15 or lower points)*	1	1	100	0	0	0	0	100
Good *(16-17-18 points)*	11	4	36	2	18	5	46	100
Very good *(19-20 points)*	22	3	14	6	28	13	58	100

When table 8 is examined, it is seen that majority of the experimental group students carrying out their learning activities by drawing graphs have very good retention. Moreover, 46% of the students having medium retention drew their graphs in the form of concept map and at the same time, the majority of the students (58%) having very good retention drew higher level of graphs in the form of concept map. Comparison of the experimental group students according to their posttest academic achievement and retention levels is presented in table 9.

Table 9. The comparison of the experimental group students in relation to their posttest academic achievement and retention levels

Retention level	N	Basic-graph drawing			Flow chart			Concept map		
		N	$\overline{X}$ (Posttest)	$\overline{X}$ (Retention)	N	$\overline{X}$ (Posttest)	$\overline{X}$ (Retention)	N	$\overline{X}$ (Posttest)	$\overline{X}$ (Retention)
Medium *(15 or lower points)*	1	1	16.0	15.0	0	-	-	0	-	-
Good *(16-17-18 points)*	11	4	17.5	17.4	2	18.0	17.5	5	18.2	18.0
Very good *(19-20 points)*	22	3	18.3	19.5	6	18.5	19.5	13	18.7	19.8

In light of the results presented in table 9, when posttest scores of the students drawing basic graphs are compared, a linear increase is observed. The same situation holds true for students drawing flow charts and concept maps. Moreover, when the table is examined, it is seen that parallel to increasing posttest academic achievement test, their retention level also increases.

It is seen that majority of the students having good retention drew their graphs in the form of basic-graph drawing and the majority of the students having very good retention drew their graphs in the form concept maps. Furthermore, the posttest academic achievement of the students having very good retention was found to be the highest. Within the framework of process-based instruction, it can be claimed that the students carrying out their learning activities by drawing graphs have higher level of achievement and retention than the students doing their learning activities by writing texts. According to the classification of the graphs, results of Kruskal Wallis H-Test analysis conducted to determine whether there is a significant difference within-groups retention levels of the experimental group students are presented in table 10.

Table 10. According to the classification of the graphs, Kruskal Wallis H-Test analysis results of the experimental students

	Graphic types	N	Mean rank	df	x^2	p
Retention	**Basic-graph drawing**	7	10.21	2	5.57	.062
	Flow chart	10	18.30			
	Concept map	17	20.03			
	Total	34				

Kruskal Wallis H-Test analysis results revealed no significant difference among the the retention levels between groups of experimental students based on the type of graphs they drew [x^2 (df=2, N=34) = 5.57, p>.05 p=.062]. In line with the purposes of the present study, t-test analysis was carried out to determine whether there is a significant difference between the problem solving scores of the experimental group and the control group and the results are presented in table 11.

Table 11. T-test analysis results for the problem solving scores of the experimental and the control groups

Groups	N	Problem solving			
		$\overline{X}$	df	t	P
Experimental group *(Drawing graph)*	34	131.7	62	-.422	.674
Control group *(Writing text)*	30	130.5			

When table 8 is examined, no significant difference was found between the problem solving scores of the experimental group and the control group (p=.674). The application can be said not to have resulted in significant difference in relation to problem solving skills.

Discussions and Results

In light of the findings of the present study, it is seen that the use of learning-aimed wiring-modal representation and drawing-modal representation based on process-based instruction has some effects on problem solving, academic achievement and retention. In association with the process-based instruction, the students were taught with the help of texts written and graphs drawn. The findings of the present study show that there is no significant difference between the posttest academic achievement and problem solving skills of the experimental group students and the control group students; yet, there is a significant difference between their retention levels favoring the experimental group students carrying out their activities by drawing graphs. This may be due to the use of learning text and graphic description modes used in experimental and control groups.

Throughout the study the students actively participated and they were provided with relaxed and flexible learning environment. The students were encouraged to be successful, provided with learning opportunities based on their own experiences and helped to enhance their learning through texts and graphs. In a study by Apps (1994) on PBI, it was concluded that the individuals should be encouraged to involve their personal experiences in the process, which would help them to understand better. When the literature on PBI is reviewed, it can be argued that the learning motivation of students encouraged, motivated and supported increases (Ashman et al., 1993; Duman, 2002). Birmingham and Garnick (1994) found that teachers can facilitate learning by using PBI and when PBI is used, students' satisfaction with their works is improved.

In research on PBI, Bolhuis (2003) stated that PBI has four main principles. First, "helping students to acquire the competency of arranging all the components involved in learning"; second, "triggering the process of information construction required to gain specialization in a specific field"; third, "helping students to see the details of affective impacts and meaning patterns, which enhances students' learning motivation"; fourth, providing students with opportunities to understand learning process and to obtain social gains." Bolhuis (2003) argues that teaching cooperative learning and social skills promotes cooperative and critical questioning skills. Various activities performed within the context of the present study (cooperative activities, group works etc.) helped students to construct information, feel more motivated, and improve their self-directing, planning and social skills. In order to help students to see and evaluate their own learning, learning activities were designed by getting them to write texts and draw graphs and in this way, the students felt responsible for their own learning and actively participated in the process. Connell and Seville (2009) state that the role of the students in PBI is working both individually and within small groups by being exposed to experiential learning to make them consciousness of their responsibilities.

Borthwick et al., (2007) argue that students' working in cooperation and providing students with settings to work in groups have positive contributions to students' many aspects ranging from their perception and understanding to their critical reflection. According to Connell and Seville (2009), the role of the instructors during the process is to arrange the learning setting in such a way that students can discover societal issues. This arrangement should consider the components of PBI (establishment of the setting, making reciprocal planning, determination of the requirements, setting learning objectives, design of learning plans, application of learning plans, evaluation of learning) while planning is being performed. In such non-traditional environment, while students are in a constant interaction with their peers and teachers, there is a need to create opportunities for them to exchange information. In the present study, the students were provided with counseling, directing, and cooperative learning opportunities and enriched learning environments. This case enabled students to exchange their ideas with effective communication and to increase their problem solving skills with presenting rich stimulus. Rodriguez-Fornells and Maydeu-Olivares (2000) emphasize that problem solving skills are one of the predictors of academic performance and former academic experiences are one of the factors effecting students' success.

In the present study, learning products were developed through the students' own experiences and perceptions and texts and graphs and the students were made aware of their responsibilities for their works while learning from their experiences. Connell and Seville (2009) concluded that students' making critical reflection on their experiences and realizing the importance of high level of participation are of great importance in teaching. Within the context of PBI, the students made use of multi-modal representations here and they drew graphs through which they created connections between their former and new information. In this way, they processed the information in a planned or concrete manner. Duman (2008) states that PBI increases the retention of information or provides the learner with many strategies when prior information needs to be remembered. One of these strategies requires the visualization of visual images in the mind.

In the present study carried out based on PBI, the control group wrote texts and the experimental group drew graphs. The students while carrying out their individual learning with these modal representations actively participated in the activities. The texts written by the control group students were classified hierarchically (from simple to complex) "descriptive, explicative, synthesizer" and the graphs drawn by the experimental group students were classified as "basic drawing, flow chart, concept map". No significant difference was found between the experimental group and the control group in terms of their academic achievement and problem solving skills. Yet, a significant difference was found between their retention levels. The reason for this difference was looked for in within-group classifications and through comparison made between the retention levels of the experimental group and the control group. In other words, it is seen that the graphical description mode used by the students in the experimental group contributes more to the permanence than the text description mode used by the students in the control group. As a result, it was found that the control group students have higher retention levels depending on increasing posttest academic achievement and text complexity level. In a similar manner, it was found that the experimental group students having high retention levels also have posttest academic achievement. Parallel to these findings of the present study, Günel et al., (2009) found that encouraging students to use modal representations (texts, graphs, mathematical modal representation etc.) may result in increasing academic achievements. In addition to this, Hand et al., (2009) emphasize that multi-modal representations embedded in texts have critical effect on understanding the topics. This may be thought to have some effects on academic achievement and retention. McDermott and Hand (2009) carried out a study with multi-modal representations and argued that teaching information through multi-modal representations may have some contributions to the development of students' comprehension. In another related study Taylor and Villanueva (2014) state that the old adage, "A picture is worth a thousand words" rings true with children who struggle to describe the way they planned and carried out their investigation. In addition to this, to increase academic achievement, for conceptual understanding and to engage in key scientific practices, students may use multi-modal representations.

Results of analysis revealed that there is a significant difference favoring the students writing synthesizer texts within the control group. However, no such difference based on the classifications of the graphs was observed within the groups of the experimental students. Atila et al., (2010) claim that if the teacher ask students to employ some other modal-representations together with learning-aimed writing, the efficiency of activities and academic achievement increase. According to Duman (2009), the brain takes the photos of concrete things rapidly while learning. The things seen are perceived by the brain and create important traces in the mind of an individual and the things learned in this way are hard to forget. This may be the reason why there is a significant difference found in the retention level favoring the experimental group in the present study. That is, graphs are easier to remember than the texts, which may have direct influence on retention level.

In light of the findings of the present study, it can be claimed that the use of learning-aimed writing and drawing-modal representations based PBI has positive impacts on problem solving skills, academic achievement and retention. In addition to this, the use of drawing modal representation has significantly more positive impacts on retention. Therefore, it seems to be clear that the use of PBI-based drawing-modal representation in learning-teaching process is important. PBI-based teaching activities can be organized in cooperation with materials designed based on different multi-modal representations can be very useful in helping students having learning and retention problems to enhance their motivation and achievement levels.

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