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Effect of Formative Quizzes on Teacher Candidates' Learning in General Chemistry

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Abstract

Formative assessment or assessment for learning is one of the most emphasized educational innovations around the world. Two of the common strategies that could be used in formative assessment are use of summative tests for formative purposes and comment only marking. We utilized these strategies in the form of formative quizzes in a general chemistry course and measured its effect on students' learning. The results of our weak-experimental design, which was conducted with 124 pre-service elementary school teachers in an undergraduate level general chemistry class, showed that formative assessment alone may not be enough to improve students' learning. The classroom context and background and attitude of students should be taken into account, which are important factors that influence student learning and achievement. In the study, two instruments and semi-structured interviews were used to collect data.

Key words: Formative assessment; Formative quizzes; General chemistry

Introduction

Assessment is an integral part of education. Assessment starts with the process of collecting information about learning (Harlen, 2013). This information then can be used for variety of purposes. When it is used to provide feedback about individuals' learning and help them achieve learning goals, they type of assessment becomes formative assessment (Black and William 1998b). In other words, formative assessment refers to the assessment activities in which evidence about the outcomes of learning are used to improve learning. This is why formative assessment is also mentioned as assessment for learning in the literature (Harlen, 2013). Influential publications such as, OECD book, Formative assessment: improving learning in secondary classrooms, (CERI, 2005) and the meta analysis by Black and Wiliam (1998a), claim that formative assessment is among the most successful educational innovations that improve learning.

Many strategies can be used for formative assessment in classrooms. Black and William (2009) explain that early work on formative assessment focused on five activities, which are 1) sharing success criteria with learners, 2) classroom questioning, 3) comment-only marking, 4) peer and self-assessment, 5) formative use of summative tests. Using quizzes for providing feedback to students is an example of formative use of summative tests and comment only marking strategies. There are many examples of using quizzes for formative purposes in many different fields, such as health sciences (Carrillo-de-la-Penã et al., 2007), medicine (Kibble, 2007; Dobson, 2008), biology (Peat and Franklin, 2002), psychology (Costa, Mullan, Cothe & Butow, 2010), computer science (Cox and Clark, 1998), chemistry (Yalaki, 2010), and math (Lawson, 1999). Many of these studies utilize computers and web based quizzes for faster assessment and feedback.

In this study, we used quizzes to offer feedback to students on their learning and help them see the areas that they need to improve. To use quizzes for formative purposes, we did not give grades to learners, we only provided written or oral feedback. Giving grades to students is not advisable in formative assessment, because it implies a judgment or competition and prevents students from focusing on the learning (Black and William, 2009). The research questions we explored were:

1. What is the effect of formative quizzes on pre-service elementary school teachers' chemistry learning?
2. What are the factors that influence the effectiveness of formative quizzes?
3. What are the reactions of pre-service elementary school teachers toward utilization of the formative quizzes?

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Method

Participants/subjects

In our study, we worked with 124 pre-service elementary school teachers (32 males and 92 females), which was a convenience sample. The study was conducted at a major university in Turkey. In Turkey, the pre-service elementary school teachers have to take one-semester, two credit hours chemistry class in the first year of their education, which is required by the national undergraduate academic program. In the general chemistry class, students were divided into four groups, each group containing around 30 students. This grouping was done to manage the class schedules and to utilize smaller classes.

Research Methodology and Design

The methodology of our research can be stated as action research, since the ultimate purpose of our research was to improve our practice. Smith (2007) explains that a common type of action research is done to improve personal practice, especially in educational fields. Action research does not aim for generalization since it is context dependent; therefore convenience sampling is a common method for defining samples. Both quantitative and qualitative data can be collected in action research based on research questions.

As the authors of this study, we taught the chemistry classes to four groups of students and conducted our research during teaching. The research was designed as two parallel weak-experimental designs with two control groups and two treatment groups since there were two instructors. As the instructors, we worked together to teach the classes as similarly as possible. We met every week during the semester to plan for next classes and evaluate the past classes. Consequently, we combined the control group and treatment group data for analysis.

The treatment groups received four non-graded, written quizzes during instruction, while the control groups were not given any quizzes. Detailed feedback was given to quizzes in in the form of written or oral comments in the treatment groups. Peer assessment and group discussions were also used which followed by instructor explanations. All groups had two midterms and one final examination during the course of the study. Students in the treatment groups were given a chance to review their midterm exam papers with oral feedback by reviewing questions and answers. Students in the control groups were not denied feedback whenever they asked for it.

Data Instruments

Both qualitative and quantitative data were collected in this study. To collect quantitative data, we developed two instruments; one was a test to measure students' general chemistry knowledge which contained 36 questions that required written answers. The other one was a survey instrument with a Likert type scale to measure students' interests toward chemistry and the chemistry course they were taking and the formative assessment techniques used during the class. The instrument contained 20 items for control group students, 26 items for treatment group students, four open ended questions for control group students, and 5 open ended questions for treatment group students. The difference in number of questions was due to the extra questions asked about the quizzes to the treatment group students. We have done validity and reliability studies of both instruments. The reliability coefficient for the General Chemistry Achievement Test (GECAT) was KR21= 0.825 and the Cronbach Alpha value for the Interest Toward Chemistry (ITC) instrument was 0.895.

In order to achieve content validity for the GECAT, we first developed a table of the course objectives and then decided how many questions we would ask for each objective and at what level. This way we tried to ensure content validity. Secondly, we have done a pilot study of the test and revised some of the questions based on the pilot study data. Finally we asked for three chemistry educators' opinions about the test to ensure validity. The GECAT instrument was applied before and after one semester of chemistry class (14 weeks in between) as pre and posttest.

To ensure validity of the ITC instrument, we asked for four colleagues' opinions about the instrument and revised some of the items based on their suggestions. We field tested the instrument with a group of students and determined its reliability before administering it to the research participants toward the end of the semester. We asked students not to write their names on the questionnaire to help them feel comfortable about writing

their responses without fear of instructor reaction. 107 students have returned the ITC instrument with their responses.

Finally, we conducted semi structured interviews with nine students. Together with the open-ended questions in the ITC instrument, interviews provided the qualitative data for the study. The interviewees were voluntary students who accepted to be interviewed for this study. The interview questions were chosen to learn about students' attitudes toward chemistry and their opinions about the chemistry course they took and also the use of formative assessment during the course. The interviews were recorded and transcribed.

Data Analysis

Independent samples t-test was used to compare the pre and post test scores of the treatment and control groups. First, we compared the pretest scores to see if there was a difference between control and treatment groups in terms of their chemistry knowledge in the beginning of the semester. Then we compared the post test scores to see if there was a difference between control and treatment groups at the end of the class.

Frequency tables of the items in the ITC instrument were generated to analyze the survey data. The qualitative data obtained through open ended questions in the ITC instrument as well as the interviews were analyzed by developing coding categories. Data was surveyed to develop codes for pieces of data that could be grouped together. As the authors of this study, we developed the codes separately and then compared. We negotiated the codes we developed and finally came up with 12 codes. These codes were used to organize the qualitative data and to make sense of it based on the framework suggested by Bogdan and Biklen (2002).

Results and Discussion

The independent samples t-test showed that there was no significant difference between pretest scores of control groups and treatment groups ($p > 0.05$, Table 1 and 2), which indicated that both groups were similar in their chemistry knowledge at the beginning of the study. The posttest scores also yielded no significant difference between control groups and treatment groups at the end of the study ($p > 0.05$, Table 3 and 4). Although there was a significant improvement when pre and post tests were compared, the gain was similar for both the control and treatment groups.

Table 1. Group statistics for pretest GECAT instrument

Group	N	Mean	Std. Deviation	Std. Error Mean
Treatment	65	6.28	4.765	.591
Control	54	7.33	4.638	.631

Table 2. Independent samples t-test for control and treatment groups (pretest GECAT instrument)

	t-test for Equality of Means		
	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	.225	-1.056	.867

Table 3. Group statistics for posttest GECAT instrument

Group	N	Mean	Std. Deviation	Std. Error Mean
Treatment	65	25.37	5.533	.686
Control	59	25.10	5.701	.742

Table 4. Independent samples t-test for control and treatment groups (posttest GECAT instrument)

	t-test for Equality of Means		
	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	.791	.268	1.009

Data obtained from the ITC instrument showed that the most participating teacher candidates had negative feelings toward chemistry. This attitude was clear in survey data and also interview data. Table 5 provides a

sample of ITC survey item with student responses. One of the items in ITC instrument was the statement "I am interested in chemistry" to which 52.3% percent of students responded as "I disagree" or "I totally disagree," 20.6% of the students responded as "I am not sure," which means totally 72.9% of the students did not approve this statement. To another item which stated, "Chemistry is one of the easy classes for me" 72.9% of the students disagreed and another 17.8% was not sure. However, this does not mean that students did not value the chemistry class and what they learned in the class. Even though they were not interested in the subject, they thought they are going to need the information they learned in the chemistry classes (at least part of it) in the future. So they agreed to the item "This course will be useful to me in the future in my job" with a total rate of 67.3%. Participants provided parallel answers to similar items in Table 5.

Students showed their negative feelings toward chemistry in their responses to the open ended questions as well. One of the open ended questions was "If you were to summarize this class in three words, what would you say?" Most of the responses to this question were negative. Students used the word "difficult" (52 out of 107) and "boring" (30 out of 107) most often in their responses. On the other hand, the total number of all o positive words that they used was just 20. The open ended questions in the ITC instrument revealed further details about students' feelings, opinions, and knowledge about chemistry and also their opinions about the chemistry class they took. The data about students' feelings towards chemistry was grouped under the code "feelings toward chemistry." For example, in response to the survey question, "What would you like to say about this class other than your responses to the other questions in this questionnaire?" one student wrote "Most of us have chosen to study social sciences and maybe most of us have chosen this department just because of our antipathy toward chemistry classes." One of the interviewed students, Ayla (pseudonym) had this to say about her friends, "Since my friends do not like science classes, they have chosen to study social sciences. They feel hate towards science fields. They come to the chemistry class with prejudices."

Table 5. A sample of ITC instrument items with student responses (% frequency)

N= 107	I Agree (Total)	I am not sure	I disagree (Total)
This course will be helpful to me in my future career.	67.3	15.9	16.8
This course involves information that I can use in my daily life.	64.5	21.5	14.0
I value what I learn in this course.	65.4	21.5	13.1
I am interested in chemistry.	27.1	20.6	52.3
Chemistry course exceeds my capacity.	30.8	18.7	50.5
This course contributes to my career.	67.3	21.5	11.2
Chemistry is a subject that interests me.	46.7	17.8	35.5
Chemistry is an easy subject for me.	9.4	17.8	72.9

Another code we developed during data analysis was "prior chemistry knowledge" and we grouped many students' responses that referred to their prior knowledge in chemistry under this code. For example, one of the students wrote in response to the question "What would you like to say about this class other than your responses to the other questions in this questionnaire?" the following answer: "Subjects are taught too fast. They are not explained simple enough. We have no knowledge in chemistry and this fact is forgotten sometimes." Another student wrote, "I have no background knowledge in chemistry and that is why after I solve questions [in class] I can't solve similar questions [later on]." Similar data was also obtained from the interviews. One of the interviewed students, Dora (pseudonym) said, "Our level is very low and you could not come down to that level. That is why we had difficulties. You should have explained things with simpler examples."

Still another code that we developed was "classroom teaching" under which data that related to students responses about our teaching methods were grouped. Majority of the students thought that more sample questions should have been solved during the classes. They specifically make a distinction in chemistry questions as "numerical" and "knowledge" questions. Numerical refers to questions that require use of math or a calculation and knowledge questions are the ones that require remembering information. They inherited this terminology from the university entrance examination jargon, which may or may not reflect the true nature of questions in the examination itself. Many students made the claim that mostly knowledge questions were asked in quizzes while they faced with numerical questions in the exams. For example, in response to the question "How this class could be taught in a more useful and more conducting way for your learning?" one student wrote: "Especially in the first quizzes, instead of only wording and memorization questions, more numerical

questions should have been asked. … More numerical question could have been solved in the class." In fact only two questions out of 10 required simple math in the first midterm examination. However, students were so afraid of such questions; many of them were just turned off when they saw them. One student wrote: "Numerical questions are asked in the exam but in the first two quizzes none was asked. I could not solve the numerical questions in the exam and that just demoralized me and affected my whole exam." In response to the questions "What are your opinions about the quizzes conducted during the class? Do you think quizzes were useful for you learning? How the quizzes should be conducted so that they are more useful?" another student wrote, "Quizzes are good. However, it would have been better if they were exactly parallel to the exams. In exams there are both numerical and wording questions; however, quizzes are either numerical or wording." Most students stated in their responses that more numerical examples should have been solved in the class. Since the class was limited to two hours per week, students were right that not enough time have been spared for solving more examples of the so called numerical questions. However, the qualitative data showed that what most students meant by saying "more numerical questions should have been solved in the classes" was really that "more questions that are very similar to the exam questions should have been solved in the classes."

One of the important data that was obtained from the interviews was related to the educational tradition that students came from that favors memorization. This data was organized under the code "educational tradition." Memorization was how most students were studying and preparing for the exams. One of the interviewed students, Layla (pseudonym), said "For example you gave a question in the [quiz], if you make a small change in the question we cannot solve it, [because] we did not understand the logic of it. Because of this, more examples should be solved in the classes." Another interviewed student, Bruce (pseudonym), said very openly "You know that we come from a tradition of memorization. We don't like to use our brains. We want everything just given to us. If you make a slightest change in a question, we can't solve it because we memorized it in its original form."

Students had very positive opinions about the quizzes we used during the semester. 68.5% of them agreed with the item "The quizzes conducted in this class helped me learn." 70.3% of them agreed with the item "The quizzes conducted in this class were very useful." Some of the interviewed students explained that quizzes have increased their frequency of studying for the chemistry course. The data provided here is a sample of what we obtained in our study which we think provides enough evidence to answer our research questions.

Conclusion

From the findings (Table 1 through 4), we can answer our first research question "What is the effect of formative quizzes on pre-service elementary school teachers' chemistry learning?" The answer is "it does not have a positive effect in every case." However, the reason for this is hidden in our answer to the second research question "What are the factors that influence the effectiveness of formative quizzes?" The answer for this question is much more complex and largely comes from the qualitative data.

Survey and interview data show that students participated in this study have mostly negative feelings toward chemistry. This fact affected the learning process significantly in the classroom. In relation to this, one unexpected experience in this study for us was that in the third quiz, almost all of the students in one of the treatment groups said that they cannot answer any of the questions and they did not even try. When asked the reason, they said that they had another exam for which they had to study and could not look up any chemistry subjects. When asked whether they remember anything from the classes, the answer was "no." This was a surprise to us because we expected students to utilize the quizzes as an opportunity for noticing their weaknesses and improve their learning using the provided feedback. It was a frustrating experience for us since no feedback can be given to unanswered questions. So, in these situations, the students were asked to work in groups and try to solve quiz questions together. They were asked to help each other and check each other's answers. What we observed often during administering quizzes was that because of their negative attitudes toward chemistry, some students easily gave up on trying to learn.

As the instructors of these classes we accept that we failed to notice how foreign chemistry was to most of the students in our classes and how little knowledge they brought about chemistry from high school. Our assumption that most students understood what we taught in the classes was wrong most of the time. In response to the ITC question, "How this class could be taught in a more useful and more conducting way for your learning?" one of the students wrote "You did not start from zero as you claimed in the beginning. You taught as if we all know [something]. … Since you started like this I was lost in all subjects."

Coming from an educational system that depends on high stakes testing, students were very much used to memorization and expected to face almost identical questions with quiz or example questions in exams. It is hard for them to break away from the traditions of the educational system that they come from and utilize the opportunities provided by formative assessment methods. Based on these findings and discussion, one of the conclusions of this study is that formative assessment alone may not be enough to improve students' learning in challenging classroom contexts such as the ones described in this study. Smith and Gorard (2005) also found in their study that formative assessment was not effective in improving student progress. However, there are many studies in the literature claiming the otherwise. We feel that the attitudes and background of students should be taken into account, which are important factors that influence student learning and achievement other than they type of assessment used.

Regarding our last research question, "What are the reactions of pre-service elementary school teachers toward utilization of the formative quizzes?" as stated in the findings, students had very positive attitudes toward the use of quizzes. They also thought that the number of four quizzes per semester, as we did in this study, is ideal. However, this positive attitude toward quizzes and the feedback given did not translate into improved test scores.

Recommendations

Strategies to make the class content more appealing and relevant to students should be utilized together with formative assessment in classes where student attitude toward the course is negative. Students should also be educated about the use of formative assessment to help them to take advantage of the opportunities brought by formative assessment before its utilization.

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