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The Effects of Online Homework on First Year Pre-Service Science Teachers' Learning Achievements of Introductory Organic Chemistry

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ABSTRACT

This study examined the effects of the introductory organic chemistry online homework on first year pre-service science teachers' learning achievements. The online homework was created using a web-based Google form in order to enhance the pre-service science teachers' learning achievements. The steps for constructing online homework were approximately described. The participants were 76 first year pre-service science teachers at Suan Sunandha Rajabhat University (SSRU). A quasi-experimental pretest-posttest design was performed in this study. The research instruments were pre- and post-tests and online homework relevant to the introductory organic chemistry. The findings unfolded that the pre-service science teachers' performance significantly improved after the implemented treatment and the online homework was an effective learning aid for improving the achievements of introductory organic chemistry learning. The correlations between online homework score and the various course elements were investigated. The moderate and statistically significant correlations were found between the online homework score of the students and the normalized gain and between the online homework score and their post-test achievements. Hence, the score results of the online homework were considered as a predictor of student test scores. A statistically significant correlation between their achievements in introductory organic chemistry chapter and their overall grades was found. In term of learning behavior, this implied that students' learning habits improved when they completed their online homework. This study also proposes that introductory organic chemistry is the hardest chapter in this general chemistry course sequence at SSRU.

KEYWORDS
online homework, introductory organic chemistry, Google form, pre-service science teachers

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Introduction

The general chemistry course is one of the required courses for first year undergraduate students entering the Program in General Science, Faculty of Education, SSRU. Though it provides a broad introduction to atomic structure, periodic table, chemical bonding, properties of gases, solids, liquids, and solutions, chemical equilibrium, acid-base reactions, electrochemistry, as well as introductory organic chemistry, it has commonly been seen as a difficult subject for non-major chemistry students. In addition, the introductory organic chemistry has generally been regarded as the most difficult part in the general chemistry course at SSRU. This chapter covered the following topics: general formulas, nomenclatures, isomers and simple reactions of organic compounds such as hydrocarbons, aromatic compounds, and organic compounds with other functional groups such as alcohol, ether, carboxylic acid, ester, amine, and amide. So, it plays an important role as a foundation of knowledge for other advanced courses. Nevertheless, it is of much concern in that many students at SSRU often receive low scores in this part resulting in low numeric course grade for the students. However, the introductory organic chemistry is still chosen as a content area to ground the students at the fundamental level.

The organic chemistry is commonly known that problem practice plays a vital role in organic chemistry performance (Szu et al., 2011). Regarding the instruction, assigning paper-based homework was a previous method to help the student learn and revise their lesson. Nonetheless, due to the scheduling of the beginning and ending of academic semester according to the ASEAN community for universities in Thailand (Piromkam et al., 2014), the instruction of introductory organic chemistry was interrupted by many more official public holidays. Consequently, they commonly failed to review and learn the lessons in a continuous and usual circumstance. Moreover, the instructor had no time to correct their assignments and assess their progress. Meanwhile, the students were not likely to complete their assignments, as well. Therefore, the researcher attempted to find a learning tool encourage them to review the learnt lessons and evaluate their performance automatically.

Online homework is one of the most effective learning tools which can assist students in practicing, exercising and reviewing previously studied lessons of coursework (Cheng, Thacker, Cardenas, & Crouch, 2004; Fynewever, 2008; Penn, Nedeff, & Gozdzik, 2000). Currently, the use of online homework is commonly found in many university courses because it creates supportive learning environments (Charlesworth & Vician, 2003) and yields more learning opportunities (Dohn, Lund, Lindhardt, & Degnebolig, 2016). In addition, some features of online systems, for instance, automatic grading responses and responsive answer keys, can help instructor save time (Cole & Todd, 2003; Hall et al., 2001; Lonn & Teasley, 2009; Muñoz de la Peña, González-Gómez, Muñoz de la Peña, Gómez-Estern, & Sánchez Sequedo, 2013; Olivier, Herson, & Sosabowski, 2001). As a result, assessing students' learning achievements through homework is not of burdensome workload any more.

In regard to online technology, Google Forms, which is buried within Google Drive ("Google drive," n.d.) is one of a free and powerful web-based tools for creating online surveys, and quizzes (Robbins, n.d.). Besides, it has three significant features over other web-based tools: 1) it can be used to create various types of questions such as short-answer, multiple choice, check boxes, scale etc. 2) it provides a quick way for instructor to do automatic grading and examine their progress and efforts in learning. 3) it can be integrated into several course activities. Recognizing the effectiveness of the Google forms and its practicality of educational use (Sinex & Chambers, 2013; Spaeth & Black, 2012), we decided to use it in order to create online homework as a learning aid for students studying the introductory organic chemistry, to enhance their learning achievements and to investigate possible correlations between online homework score and various course elements.

Method

Research Design

This research design was based on the use of online homework to enhance students' learning achievements on the introductory organic chemistry. The design was adapted from previous literature research (Chamala et al., 2006; Cheng et al., 2004; Nguyen & Kulm, 2005; Penn et al., 2000). In this quasi-experimental study, the string of process started from taking a pre-test, completing online homework and taking a post-test to measure their learning of introductory organic chemistry.

Participants

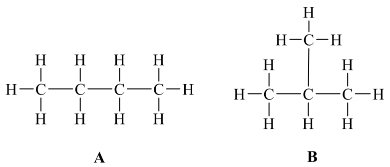
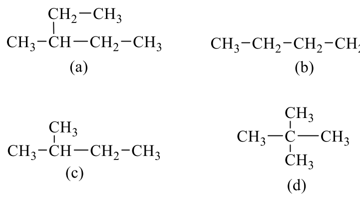
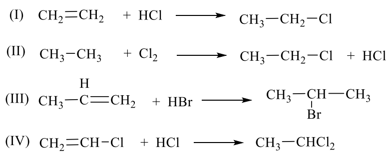
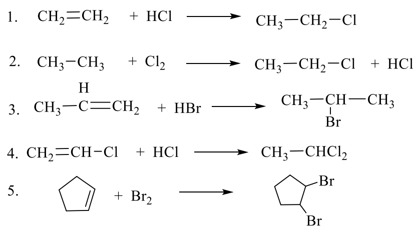
The participants in this experiment were selected based on the fact that they demonstrated low academic performance in the previous semester. Using that criteria, 78 first year pre-service science teachers who enrolled in general chemistry (SCE 1403) were chosen. This three credit course met once a week for 180 minutes in total (those 60 minute periods). The introductory organic chemistry course lasted for four weeks. The study was conducted during the second semester of the academic year 2015. The students who enrolled in this course were from the General Science Program in the Faculty of Education at Suan Sunandha Rajabhat University, Thailand.

Research Instruments

The first year pre-service science teachers' learning achievements were examined using three main instruments. 1) a paper-based pre-test, 2) online homework, and 3) a paper-based post-test.

Pre- and post-tests of introductory organic chemistry contained 30 multiple-choice questions. Each question offered five possible answers with only one correct answer. At first, the test, which consisted of 50 items, was piloted on students who were registered in general chemistry during the previous academic year. The test items were selected from 50 possible items ranged from difficulty index (p) from 0.38 to 0.76, and a discrimination index (r) from 0.36 to 0.60.

Table 1. Samples of introductory organic chemistry online homework questions and test questions

Topics[a]	Sample online questions	Sample test questions (multiple choice: five different choices)
General formula	Write the general formula of alkane that has 9 carbon atoms. (short-answer question) Key: C_9H_{20}	Which of the following formulas represents an alkane that has 12 carbon atoms? 1. $C_{12}H_{24}$ 2. $C_{26}H_{12}$ 3. $C_{12}H_{26}$ 4. $C_{12}H_{22}$ 5. $C_{12}H_{12}$ Key: 3. $C_{12}H_{26}$
Structural isomers	What is the relationship between the following compounds shown below?  1. same compound 2. structural isomer 3. same boiling point 4. enantiomer 5. there is no relationship. Key: 2. structural isomer	Consider compounds below;  Which of the compounds can exhibit structural isomerism? 1. (a) and (b) 2. (b) and (c) 3. (c) and (d) 4. (b), (c) and (d) 5. (a), (b), (c) and (d) Key: 4. (b), (c) and (d)
Simple organic reactions	Consider reactions below;  Which of the following reactions represents addition reaction? 1. (I) and (II) 2. (II) and (IV) 3. (I), (II) and (III) 4. (I), (III) and (IV) 5. (II) only Key: choice 4	Which of the following reactions represents a substitution reaction?  Key: choice 2

[a] Topics relevant to introductory organic chemistry

The online homework was created by using Google form and the steps were presented as follows;

1. The Google account ("Creating a Google Account," n.d.) with Chrome browser and enables Google drive was required to create the online practice test.
2. After Google drive was accessed, click on the "NEW" icon.
3. Tap Google Form to open its new browser.
4. Name the form title and choose the multiple choice option at the right of the form.
5. Fill the questions and choices on each item.
6. Type text that respondents will see after completing the online homework.

In order to get the web link of the created online homework, click on the SEND icon and copy the link to post on the instructor's website. For the additional details for constructing online homework see following web sites (Wolber, 2012a, 2012b). After the students responded to the online homework, the respondents' score was graded by using Flubaroo add-on and immediately shared their grad via respondents email ("Create an Online Quiz in Google Docs," n.d.).

The online homework was constructed from existing problems in chemistry textbooks (Chang, 2010; Silberberg & Amateis, 2014) and standardized tests evaluating the academic performance in chemistry. The instructor chose the questions relevant to the course content. The test questions had a strong focus on naming organic compounds, writing general formulas of organic compounds, classifying functional groups, and predicting products from basic organic reactions. The selected problems were translated from English into the Thai language in order to decrease the risk of any language interference and in order to make the problems more comprehensible.

For comparison purposes, the samples online homework and test questions used by the instructor are given in Table 1. The online homework consisted of five short-answer items and 35 multiple-choice items with five possible answers each. The questions and choices in the online homework varied each time students repeated the homework. The students received their scores and the answer key through their emails after their accomplishments.

Procedure

The procedure of conducting this study was comprised of the major 3 stages below:

First, the first year pre-service science teachers completed the paper-based pre-tests of introductory organic chemistry. Conventional lecture-discussion methods that have been widely used in teaching general chemistry (Arasasingham, Taagepera, Potter, Martorell, & Lonjers, 2005) were utilized in this course. A few examples problems that were not present in either the online homework or the tests were discussed and practiced in the classroom. The answers to these problems were also posted by the instructor.

Using a technological approach to support learning came the second. Creating a Gmail account was demonstrated in the classroom. The students were taught how to access the online homework, which was created via Google Forms. The homework link was posted on the instructor's website so that they can complete the online homework at any time and any place they wished. The adapted feedback for each answer was customized to be delivered to their emails for the reason of convenience in checking the answers and total scores after their completion. During the preparation, the participants were instructed to complete the three separate online homework assignments. The scheduling of online homework assignments was, then, announced in class. After the lecture had finished, the first homework was posted and available only seven days. After this period, the link to the online homework was posted again and expired on the final examination day. Through this learning system, the students were allowed to repeat the online homework as many times as they wished.

The final stage of this study involved with taking a paper-based post-test of the introductory organic chemistry. Then, the exams were checked for scoring and the score results were analyzed to obtain the statistic parameters. The correlations between various course elements were also investigated.

Results

Overall, only 76 of the 78 students (97%) completed the first, second, and third online homework assignments. The two students who failed to complete the three assignments because they rarely attended class lectures when the online homework assignments were given and did not attend a lecture on the day that grade evaluating was announced.

Table 2. Practice attempts and average scores (N = 76) of online homework

Attempt	Mean score	SD
1	25.94	7.13
2	28.41	6.16
3	30.57	3.21

The mean score on the first attempt of the online homework assignments for the 76 completers was 25.94 (SD = 7.13). The mean score of the 76 students who repeated the online homework for the second time was 28.41 (SD = 6.16). The highest mean score of the online homework was obtained in the third attempt (mean 30.57, SD = 3.21). The low standard deviation that was obtained in the third attempt implies that the score was assembled closely around the mean. The trend of the mean score (shown in Table 2) indicates that the mean score of online homework slightly increased when the number of attempts increased. Interestingly, there were a few students who retook the online homework for the fourth time, however, not all 76 students who had completed the first, second, and third attempts all completed the fourth attempt. Therefore, the result of the fourth practice attempt was not examined.

Table 3. Pre-service science teachers' learning achievements of introductory organic chemistry (N =76)

	Full score	Pre-test				Post-test			
		Mean	SD	(%)	Description	Mean	SD	(%)	Description
Introductory organic chemistry	30	7.46	2.22	24.87	poor	21.25	4.68	70.83	very satisfactory

As shown in Table 3, the statistical analysis indicated that the students achieved average post-achievement score of introductory organic chemistry (mean 21.25, SD = 4.68) was greater than the average pre-achievement score (mean 7.46, SD = 2.22). The mean score of the test improved significantly from 24.87% (poor) to 70.83% (very satisfactory) after the online homework treatment.

Table 4. Results of paired sample *t*-test measuring the difference between pre-test score and post-test score (absolute gain)

	Absolute Gain			*t*-test	
	Mean	SD	(%)	*t*	*p*
Introductory organic chemistry	13.79	4.31	45.96	27.88	.000

Table 4 shows that the absolute gain of the class was 45.96% (mean, 13.79, SD = 4.31). According to a paired sample *t*-test analysis, the significant difference between average post-test scores and average pre-test scores was observed at a *p*-value less than 0.05. This means that students' learning achievements in introductory organic chemistry was significantly improved due to the online homework treatment

In order to confirm the enhancement of students' learning achievements resulting from the online homework and to account for each students' learning ability, the normalized gain (g) (Hake, 1998) was investigated. It is defined as the different score between the post-test and pre-test results divided by the maximum possible increase. The formula is shown in equation 1;

$$g = \frac{\text{posttest} - \text{pretest}}{\text{max} - \text{pretest}} \times 100 \qquad \ldots(1)$$

where max is the full score of the test. The data of each students' normalized gain was plotted versus a number of students (shown in Figure 1). The average value of normalized gain for the class was 61.66% (SD = 19.95). This value is statically significant with $p = 0.000$.

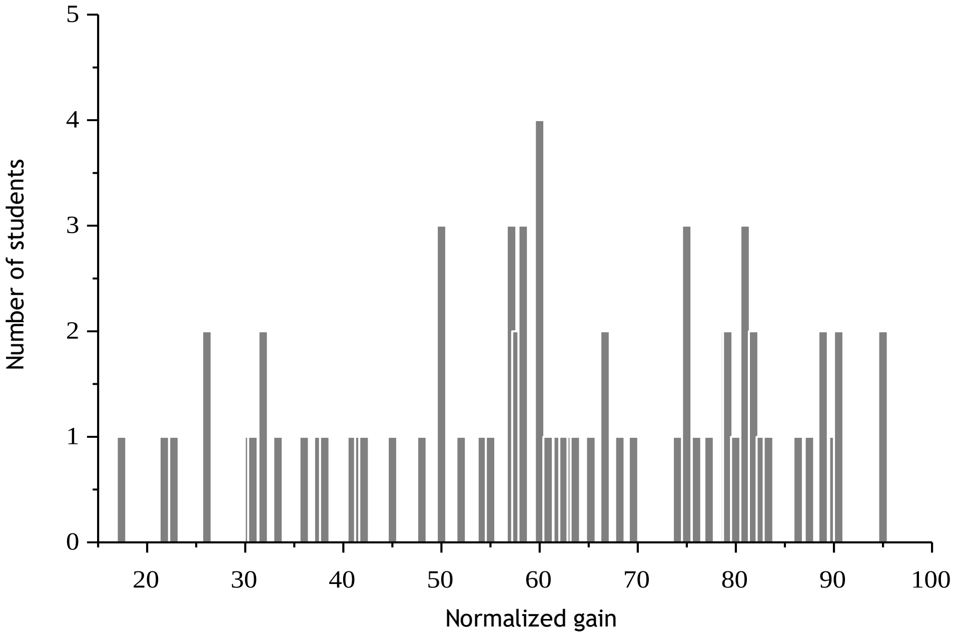


Figure 1. The distribution of normalized gains for first year pre-service science teachers

Table 5. Correlations among mean online homework score, normalized gain, pre-test score, post-test score, and final numeric course grade, after the online homework treatment

	Normalized gain	Pre-test	Post-test	Final numeric course grade
Average online homework scores	0.48 (p = 0.000)	0.36 (p = 0.001)	0.51 (p = 0.000)	0.55 (p = 0.000)
Normalized gain	-	0.25 (p = 0.030)	0.99 (p = 0.000)	0.83 (p = 0.000)

Preliminary results (pre-test and post-test score, absolute gain) indicated that the online homework was helpful for the students' learning achievements. We consequently investigated the correlations between average online homework score and various course elements (Table 5). Initially, we expected that the statistically significant correlation between the average online homework score and the normalized gain needed to be observed ($r = 0.48$, $p = 0.000$). There were moderate and statistically significant correlations between the average online homework score and the pre-test score ($r = 0.36$, $p = 0.001$) and a correlation between the average online homework score and the post-test score ($r = 0.51$, $p = 0.000$). We also found a statistically significant correlation between the average online homework score and the final numeric course grade ($r = 0.55$, $p = 0.000$). These positive correlations correspond to the results in previous reports on the correlations between average online homework score and these course elements

(Chen & Baldi, 2008; Fynewever, 2008; Parker & Loudon, 2013; S. Pollock, 2004; Richards-Babb, Curtis, Georgieva, & Penn, 2015; Richards-Babb & Jackson, 2011).

We further extended to explore the correlations between normalized gain and three values of course elements: pre-test score, post-test score, and final numeric course grade. We found a small correlation between normalized gain and pre-test ($r = 0.25$, $p = 0.030$). On the other hand, we found a high and statistically significant correlation between normalized gain and post-test ($r = 0.99$, $p = 0.000$), and a correlation between normalized gain and final numeric course grade ($r = 0.83$, $p = 0.000$). These positive correlations are similar to the finding in previous reports (Meltzer, 2002; S. J. Pollock, 2005).

Discussion

This research was performed in order to investigate the use of online homework affecting the performance of first year pre-service science teacher students studying introductory organic chemistry chapter.

It can be seen that pre-service teachers in science subjects obtained higher scores when they repeated online homework multiple times (Table 2). This may have been resulted from the fact that they had more opportunities to practice and review the lessons which they had already studied. This reflects that the pre-service science teachers can learn more when they complete online homework (Nguyen & Kulm, 2005).

The post-achievements of introductory organic chemistry were higher than their pre-achievements after the exposure to online homework treatment (Table 3). The pre-service science teachers' learning achievements were increased by 45.96% after the exposure to the online homework treatment (Table 4). Therefore, our research indicates that the online homework practices can enhance the pre-service science teachers' learning achievements of introductory organic chemistry—this finding is in accordance with previous researchers (Chen & Baldi, 2008; Parker & Loudon, 2013; Penn et al., 2000; Richards-Babb & Jackson, 2011).

To confirm that the online homework plays an important role in the increase of learning achievements of introductory organic chemistry, the correlation between average online homework score and various course elements was investigated. The mean of online homework score showed a correlation with their pre-achievements, as seen in Table 5. This means that the students possessing low scores in the pre-test, also had low scores on the online homework. On the other hand, the mean of homework score was significantly correlated with the normalized gain ($r = 0.48$, $p < 0.05$) and post-test scores ($r = 0.51$, $p < 0.05$), as shown in Table 5. This means that pre-service science teachers who obtained a high score on the online homework practice, also obtained high performance on the introductory organic chemistry test. This result implies that the online homework score could yield the probability of exam scores in introductory organic chemistry. One explanation that can be used to describe this observation is that the adapted feedback and score which students obtained after completing the online homework helped the students evaluate themselves before the final exam.

On the basis of this finding, we can conclude that pre-service science teachers can take advantages of online homework as a learning aid without restrictions of time and place to help to improve their learning achievements. In addition, it can be said that online homework performance is a significant factor for the enhancement of learning achievements of introductory organic chemistry—as previous studies (Chamala et al., 2006; Parker & Loudon, 2013; Penn et al., 2000; Raines & Clark, 2012; Richards-Babb et al., 2015).

As mentioned in the introduction, the students always obtain low achievements in the introductory organic chemistry part of their general chemistry course which resulting in low final grades. We surprisingly found a correlation between the average online homework score and final numeric course grade ($r = 0.55$, $p < 0.05$) after the online homework treatment. Even though weighting of this part of the course was only 25% of the whole course—it has a great effect on grade evaluation. A strong correlation between the normalized gain and the overall grade ($r = 0.83$, $p < 0.05$) was also found in this experiment as seen in Table 5. This means that the pre-service science teachers who obtained a high performance in the introductory organic chemistry chapter, also obtained a high overall grade for this general chemistry course. These positive correlation findings corroborate the results of Richards-Babb (2015) who indicated that online homework could improve students' study habits. Furthermore, this result implies that introductory organic chemistry is more difficult than the other segments of the general chemistry course.

Conclusion

We used the free web-based tool, Google Form, to create the online homework that was applied as a treatment to investigate pre-service science teachers' introductory organic chemistry performance. This investigation revealed that the online homework assignments greatly supported their improvement in introductory organic chemistry chapter. The progress was obvious because of their attempts and helpful immediate feedback. Besides, they were able to use online homework as a learning aid to prepare themselves for the examination. The online homework performance was assumed as a good predictor to estimate the test achievements and played an important factor to develop our students' learning achievements and strategy to improve the study habits of our students. This was reflected by the strong correlation results between the normalized gain and the overall grade. Furthermore, results suggested that introductory organic chemistry is the most difficult chapter in our general chemistry course.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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