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Development of the learning management process to enhance the chemistry learning achievement and conceptual comprehension on organic chemistry using the Posner's approach with design-based research

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Abstract

The research objectives were: 1) to study misconceptions in organic chemistry; 2) to design and develop a learning process to promote learning achievement and conceptual comprehension by applying Posner's approach in accordance with the design-based research method; and 3) to study the results from the implementation of the learning process to promote learning achievement and conceptual comprehension by applying Posner's approach in accordance with the design-based research method. The samples were 52 students in Grade 12 (25 students for the experimental group and 27 students for the control group). The research instruments were: 1) lesson plans based on the Posner approach with design-based research; 2) general lesson plans; 3) an organic chemistry achievement test; and 4) an organic chemistry conceptual comprehension test. The data were analyzed using the mean, standard deviation, skewness, kurtosis, multivariate analysis of variance (MANOVA), and HotellingT^2. The research findings were: 1) there were nine misconceptions in organic chemistry; 2) the learning process development to enhance organic chemistry achievement and conceptual comprehension based on the Posner approach with design-based research had four conditions: (i) not understanding in terms of learning, (ii) teaching for conceptual understanding, (iii) linking new concepts to the original concept, and (iv) the expansion of concepts to learn to solve new problems or situations. Furthermore, the learning process in classroom should be a competitive situation; 3) organic chemistry achievement and conceptual comprehension scores of the students in the experimental group were significantly higher than for the control group at a level of 0.05. In addition, the organic chemistry achievement and conceptual comprehension post-test scores of students in the experimental group were significantly higher than the pre-test scores at a level of 0.05.

Introduction

The subject of sciences is based on the principle of rationality that can be explained using academic principles. The arrangement of learning science subjects may allow students to do experiments to prove the phenomena as stated by rules or theories. However, there are some

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contents that students cannot experiment with because such contents are abstract or cannot be reflected to be tangible, such as the subject of chemistry, which is a science that is related to the study on the levels of atoms, molecules, ions, properties of matters, chemical signs, chemical equations, chemical formulas, and the application of mathematics to the subject (Johnstone, 2000). Most problems for teaching are associated with the fact that students cannot imagine the contents in order to attain accurate concepts. This may be because each student has a particular background, based on past experiences or learning that is different from that of others, which leads to their individual thinking method, imagination, and estimation of answers. Consequently, students may develop misconceptions from learning. This limits students from attaining true knowledge, which is difficult to change. Misconceptions may occur in all phases of learning (Suchiwa, 2002). Therefore, misconception obstructs the learning of new knowledge that is based on preliminary knowledge. Once this happens, the misconception will be with students for a long period because the students have memorized and understood it already until it is able to be corrected with difficultly (Treagust & Duit, 2009).

Teo, Goh, and Yeo (2014) synthesized the trends of chemical studies from 650 articles and discovered that during the period between 2004 and 2013, 7.7 percent of the studied research works were about approaches or changes of concepts. The results from the synthesis reflect the significance of teachers who emphasize studying approaches or on misconceptions in the subject of chemistry. It also discovered that one of the methods implemented to correct misconceptions in many research works was the set of conditions for the change of concept by Posner, Strike, Hewson, and Gertzog (1982) who proposed conditions for changing concepts that can be implemented in teaching and learning. To succeed in changing concepts, teachers use various teaching methods other than to give lecturers, such as experiments, demonstrations, and classroom discussion to urge students to develop their thinking process. In addition, during the teaching and learning, teachers must frequently question students. The conditions for the changes of concepts and roles of teachers, as Posner et al. proposed, enable students to attain true knowledge from the learning.

To correct misconceptions is time-consuming because students have retained and will retain incorrect knowledge for a long period and the corrective process includes many steps including designing and planning. Carey (2000) recommended that science educatorscan correct the misconceptionsusing various techniques, such as educational research, classroom practice, and training the teachers by starting with diagnosis of students and their initial understanding of content knowledge by studying the mechanisms underlying the conceptual change, which is a very important goal of science educational research; Third, changing the classroom culture by building explanations and understanding of students followed by a comparison of issues on how the students understand with the nature of scientific knowledge in general. All the aforementioned will play significant roles in understanding the problem states related with the misconceptions of students and enhance science educators to develop learning innovations to correct the misconceptions. Hence, it is worthwhile to conduct a research project with a methodology called 'design-based research' which is a research method that uses design as the base and has the aim of developing learning innovations using the research process in designing theories and creating innovations. The core principle is the repeated operations during the research to improve theories and innovations until they can be actually implemented to students (Wongwanit, 2016). Wang and Hannafin (2005) explained the five core features of design-based research: 1) emphasis on practice because during the work, there must be extension or modification of the relevant approaches or theories; 2) the nature of the research problems in the process, which are truly emerging during the operation; 3) interactions during the operation, with the repetitive and cyclical modification, which means the design has to be flexible; 4) integration of research methods to a diversity of operations; and 5) the consistency of the contents of the research because there is a summary of research results for each research cycle.

From the aforementioned rationale, the researcher was interested in studying the conceptual comprehension and learning achievement of the subject of organic chemistry by twelfth grade students because the subject incorporates a diversity of learning activities, experiments, and investigation that rely on interpretation. Al-Balusshi, Ambusaidi, Al-Shuaili, & Taylor (2012) surveyed misconceptions in the subject of chemistry and discovered that organic chemistry is a topic in which students had a great level of misconception. In this research project, the approach of concept change by Posner et al. (1982) was applied to the arrangement of learning activities. The design-based research method was applied to designing activities during the research work to promote learning achievement and conceptual comprehension, and to design and modify the learning process to suit the contexts of students.

Objectives

The objectives of this research were: 1) to study misconception in organic chemistry; 2) to design and develop learning process to promote learning achievement and conceptual comprehension by applying Posner's approach in accordance with the design-based research method; and 3) to study the results from the implementation of the learning process to promote learning achievement and conceptual comprehension by applying Posner's approach in accordance with the design-based research method.

Literature Review

Learning achievement includes an individual's knowledge and capabilities that result from the learning process that teachers have pre-arranged in accordance with the predetermined plans for a certain period of time. Alternatively, learning effectively can be a set of massive experiences an individual has attained from teaching and learning, which makes that individual change his/her behavior. Such experiences can be knowledge or skills. In general, the

emphasis is put on neural skills or thinking, which reflect the learning from the past learning that each individual has experienced (Thawirat, 1986).

Misconception is the perception and interpretation of contents that deviate from actual approaches or facts. When perceived, the misconception will deeply and firmly root into a person's mind. One of the approaches to change misconception is the set of the conditions for changing concept by Posner et al. (1982) who proposed four conditions for changing the concept, which can be implemented with teaching and learning. The first condition is that there must be dissatisfaction with the existing concept, and teachers must change the misconceptions of students. Thus, before adjusting themselves, students must have accumulated frustration or loss of confidence in their own capabilities to solve the problems they are facing. The second condition is that a new conception must be intelligible. The third condition is that a new conception must appear initially plausible, which means the studied concept must at least show that it can be used for solving the unsolved problems students are experiencing. The other concept is that a new concept should suggest the possibility of a fruitful research program, which allows students to investigate and research in order to solve problems in different circumstances.

Therefore, the educational researcherstried to find ways to promote learning achievement and conceptual comprehension by conducting the new research using various research designs. Design-based research is a new research design thatstarts with theories, approaches, or principles that are used as the foundation for the desiring, development, and improvement of the selected ideas, theories, or principles through a repetitive process that leads to the attainment of the form that is appropriate and agreeable to the contexts of target groups. Designing a process requires collaboration from people with various fields of expertise and has five main attributes:1) practicality; 2) research based; 3) repetition, interactions, and flexibility; 4) integration; and 5) adherence to contexts (Wang & Hannafin, 2005). The achieved result is the innovation that suits the students.

For the research conceptual framework, from studying documents and other research works related to learning achievement and conceptual comprehension in the subject of chemistry, it was discovered that misconception stems from various causes, and negatively affects students by hindering them from having correct comprehension of the contents and results in them having understanding that deviates from true knowledge. Posner et al. (1982) explained the four main conditions for correcting misconception from the aforementioned that there must be dissatisfaction with the existing concept and an intelligible, appearing initially plausible option, and the possibility of a fruitful research program suggestion. These conditions can be applied to classroom learning and can lead to higher learning achievements. The aforementioned conditions concur with the findings from research works by Penwong (2003) and Lapbun (2000), which concluded that students who participate in learning and teaching that meet the conditions for changing concepts by Posner have a lower level of misconception than students having normal learning course and the former students also have a higher level of learning achievement. This is especially true for the improvement of the learning process to correct misconceptions in the subject of chemistry to fit students, which the researcher carried out by implementing the design-based research technique. Keles, Cepni, Aydin, and Hasiloglu (2011)examined the effect of conceptual change texts used by fifth-grade students in science and technology courses on eliminating misconception and concluded that the explanation of the content was significantly decreased from the pre-test. For the achievement of students affected by the conceptual change approach, the study of Koparan, Yildiz, Kogce, and Guven (2010)found that the instructional material can significantly increase the achievement of the students in the experimental groups. Wang and Hannafin (2005) explained that design-based research is a research technique that aims to improve the research process by applying the results reflected from previous research cycles to the improvement of latter research cycles that are repetitively carried out in order to attain new patterns that fit the contexts of target groups. Wongwanit (2016) mentioned the implementation of design-based research technique to the development of educational innovations as a process that leads to the attainment of educational innovations, which relies on changes in thinking, which lead to a design that is the product that is tested on students. This concept concurs with the findings from research by Chen (2007) who implemented the design-based research technique to design learning in accordance with actual contexts. The researcher also applied this concept to the study on the results from the implementation of learning process to boosting students' learning achievement and conceptual comprehension in the subject of chemistry and the topic of organic chemistry.

Methods

The research methodology was divided into three phases. The first phase was the study of the misconception in the matter of organic chemistry in the subject of chemistry, using the qualitative research method, which started with the analysis on the expected learning achievement in organic chemistry in order to determine the research questions. Data concerning misconception in organic chemistry were collected using the informal interview technique. The four main, open-ended questions in the informal interviews were: 1) "What is the student's organic chemistry learning achievement?" 2) "What are the causes of low student achievement?" 3) "What are the topics that the students misunderstand about organic chemistry and what are the students' perceptions of the concept?" and 4) 'Does the teacher have a solution to the misunderstanding of organic chemistry?" The key informants were three teachers who worked in a public school, who were selected using the purposive sampling technique with the following criteria: 1) had a master's degree of sciences in chemistry or a field of science teaching a chemistry subject; and 2) had experience in teaching the subject of chemistry for more than 5 years.

Phase 2 incorporated the design and development of the learning process that boosts learning achievement and

conceptual comprehension in the matter of organic chemistry in the subject of chemistry with the implementation of Posner's approach. The researcher created the plan for arranging the learning with the conditions for changing the concept, proposed by Posner, used as the preliminary conditions for the designing of the learning process, in order to prevent misconception in the target group, in accordance with the issues of qualitative study as in Phase 1. Afterward, the designed process was checked for accuracy and adjusted in accordance with the suggestions from five experts in teaching sciences. Then, the learning plan was applied to the targets. During the research work, the researcher used the reflected ideas from each learning activity to improve the learning process to making it more concurrent to the target groups in accordance with the contexts. This was the design-based research technique.

Phase 3 consisted of the study on the results from the implementation of the learning process that promoted learning achievement and conceptual comprehension on the matter of organic chemistry in the subject of chemistry. The research populations were 82 twelfth-grade students. The samples were 52 twelfth-grade students. The appropriate sample size was determined using the G*Power program, version 3.0.10., the effect size was 0.90, based on research work by Sibua (2015), with a significance level of 0.05, and the power of the test was 0.80. The samples were selected using a two-stage sampling technique. In the first stage, the samples were selected based on a simple random sampling technique using the classroom as the unit of analysis (knowledge and capabilities of students in each classroom varied). In stage two, samples were divided into two groups, the first group of which consisted of 25 samples being the experimented ones whilst the other group consisted of 27 in the control The experimental period was 6 weeks; the time was 3 h per week. The total experimental time was 18 h. The research design was a pre-test and post-test control group design. Tools for collecting the desired data were a questionnaire on learning achievement and conceptual comprehension. The questionnaire consisted of 20 items in two-tier questions, each of which had two parts, the first of which was the question to assess the learning achievement which consisted of four multiple choices from which the respondent could choose, and the other was the question to assess the conceptual comprehension which consisted of four multiple choices from which the respondent could choose to explain the cause for the answer to the question in the first part. The students were allocated 1 point for the correct answer and 0 points for the incorrect answer. The questionnaire had content validity (IOC) scores that fell in the range 0.60−1.00. The difficulty indices of the questionnaire to assess learning achievement were in the range 0.33−0.80, with discrimination indices in the range 0.25−1.00 and the Kuder Richardson Reliability (KR-20) score was 0.92. The questionnaire to assess conceptual comprehension had difficulty indices in the range 0.07−0.08, discrimination indices in the range 0.13−1.00, and the Kuder Richardson Reliability (KR-20) score was 0.84. Scores from the assessment of learning achievement and conceptual comprehension were analyzed with descriptive statistics, namely, means and standard deviations. Research hypotheses were tested using one-way multivariate analysis of variance (MANOVA) and Hotelling's T^2 test techniques.

Results

1. Concerning the misconception in the matter of organic chemistry in the subject of chemistry, it was discovered from the study there were nine main issues: 1) confusion of carbonic (H_2CO_3) compound with carboxylic compound; 2) writing of linear structure and angle between carbon atom and triple bond carbon; 3) misconception of isomers; 4) differences in the reactions of open chain alkanes and the reactions of cycloalkanes, with the same number of carbon atoms; 5) writing of structures hydrocarbon compounds that were cyclical for compounds with molecules that had triple bonds; 6) occurrence of geometric isomers; 7) ranking of the accelerations of the occurrence of hydrocarbon compounds; 8) acid-base properties of phenol compounds; and 9) occurrence of hydrogen bonds among molecules of hydrocarbon compound.

2. Designing the learning process that promoted learning achievement and conceptual comprehension in the matter of organic chemistry in the subject of chemistry by implementing Posner's approach in accordance with the design-based research method led to the findings that during the course of the designing that was based on Posner's approach of conditions, the researcher had adjusted the learning process in accordance with the conditions for changing the concept in order to fit the students. The adjustment was based on four conditions: 1) inability to understand the learnt topic; 2) teaching to generate comprehension on the concept; 3) the linkage between the new concept and the concept that has been learnt before; and 4) the extension of the learnt concept for solving new problems or situations. In addition, it was also found that the in-class learning process must occur in a competitive atmosphere.

3. The findings from the study on the results from the implementation of the learning process that promotes learning achievement and conceptual comprehension in the matter of organic chemistry in the subject of chemistry by implementing Posner's approach in accordance with the design-based research method showed that students in the experimental group, to whom the designed learning process was applied, had the means of learning achievement and conceptual comprehension in the topic of organic chemistry that were at a higher level than those of students in the controlled group, to whom normal learning process was applied, with statistical significance of 0.05 ($F = 35.85$, $p = .00$) (Table 3). The means of the learning achievement of the experimental group and the controlled group were 15.76 and 8.76, respectively (Table 1), and the effect size was at the high level (Cohen's $d = 2.32$). The means of the conceptual comprehension of the experimental group and the controlled group were 12.17 and 7.80, respectively (Table 2), and the effect size was at the high level (Cohen's $d = 1.44$). The results from the comparison of the means of learning achievement and conceptual comprehension if the experimental group to which the earning process in accordance with Posner's approach and the design-based research method showed that the means of learning

Table 1
Comparison of learning achievement between experimental and control groups

Group	n	Learning achievement score (pretest)				Learning achievement score (posttest)			
		M	SD	Sk	Ku	*M*	SD	Sk	Ku
Experiment	25	4.65	2.16	0.23	−0.39	15.76	2.99	−0.97	−1.47
Control	27	5.64	1.88	0.24	0.12	8.76	3.04	−0.44	−0.93

Table 2
Results of statistical analysis of basic statistics on conceptual comprehension

Group	n	Conceptual comprehension score (pretest)				Conceptual comprehension score (posttest)			
		M	SD	Sk	Ku	*M*	SD	Sk	Ku
Experiment	25	4.84	1.77	−0.53	0.10	12.17	3.04	0.19	−0.99
Control	27	5.45	1.90	0.09	0.43	7.80	3.03	−0.65	−0.54

achievement and conceptual comprehension of the experimental group after the learning were higher than those before the learning with statistical significance of 0.05 (F = 119.81, p = .00) (Table 4). The means of the learning achievement after and before the learning were 15.76 and 4.65, respectively (Table 1), with the effect size at the high level (Cohen's d = 4.26). The means of the conceptual comprehension after and before the learning were 12.17 and 4.84, respectively (Table 2), with the effect size at the high level (Cohen's d = 2.95).

Discussion

From the research, it is discovered that the design of the learning process that promotes learning achievement and conceptual comprehension depended on four conditions for changing the concept: 1) the inability to understand the learnt topic; 2) teaching to generate comprehension of the concept; 3) the linkage between the new concept and the concept that has been learnt before; and 4) extension of the learnt concept for solving new problems or situations. The results from this study were the designing principle or theory that emerged from the adjustment and repetition of the process used on the same samples. From this research, it was discovered that designing and adjustment of the concept in accordance with Posner's approach led to higher means of learning achievement and conceptual comprehension of students to whom the designed learning process was applied because the process is suitable for students and creates a learning atmosphere that facilitates learning. Such findings concur with the ideas of Flach and Constantin (2015) who stated that the success of new teaching processes depends on teachers' abilities to invent and use innovative teaching techniques and motivating techniques that are designed to be successfully implemented. In addition, the learning process must create a competitive atmosphere because competitiveness is a factor that influences students to pay attention to the learning, which is reflected through students' eagerness to answer questions and proposing themselves to represent the entire class in discussion on the problems before the entire class.

From the implementation of the learning process that promotes learning achievement and conceptual comprehension in the matter of organic chemistry in the subject of chemistry by implementing Posner's approach in accordance with the design-based research method, it was discovered that students to whom the learning process was applied had means of learning achievement and conceptual

Table 3
Results of MANOVA on learning achievement score and conceptual comprehension score between experimental and control group

Effect	Multivariate test	Value	F	Hypothesis df	Error df	*p*
Treatment	Pillai's Trace	0.59	35.85*	2.00	49.00	.00
	Wilks' Lambda	0.40	35.85*	2.00	49.00	.00
	Hotelling's Trace	1.46	35.85*	2.00	49.00	.00
	Roy's Largest Root	1.46	35.85*	2.00	49.00	.00

Tests of Between-Subjects Effects

Sources of variance	Dependent variable	SS	df	MS	F	*p*
Treatment	Learning achievement	637.94	1	637.94	69.75*	.00
	Conceptual comprehension	250.29	1	250.29	27.12*	.00
Error	Learning achievement	457.30	50	9.14	457.30	
	Conceptual comprehension	461.37	50	9.22	461.37	
Total	Learning achievement	8740.06	52			
	Conceptual comprehension	5825.36	52			

Box's M = 2.74, F = 0.87, df1 = 3, df2 = 563252, p = .45
Levene's Test: learning achievement F = 0.28, p = .60, conceptual comprehension F = 0.06, p = .81
Bartlett's Test of Sphericity: χ^2 = 63.82, df = 1, p = .00
*p < .05

Table 4
Results of Hotelling's T^2 test on learning achievement and conceptual comprehension between pretest and posttest score

Effect	Multivariate Tests	Value	F	Hypothesis df	Error df	*p*
Time	Pillai's Trace	0.83	119.81*	2.00	47.00	.00
	Wilks' Lambda	0.16	119.81*	2.00	47.00	.00
	Hotelling's Trace	5.09	119.81*	2.00	47.00	.00
	Roy's Largest Root	5.09	119.81*	2.00	47.00	.00

Tests of Between-Subjects Effects

Sources of variance	Dependent variable	SS	df	MS	F	*p*
Time	Learning achievement	1545.29	1	1545.29	226.46*	.00
	Conceptual comprehension	675.77	1	675.77	108.93*	.00
Error	Learning achievement	327.54	48	6.82		
	Conceptual comprehension	297.78	48	6.20		
Total	Learning achievement	7080.64	50			
	Conceptual comprehension	4603.35	50			

Box's M = 14.78, F = 4.70, df1 = 3, df2 = 414720, p = .00
Levene's Test: learning achievement F = 6.53, p = .01, conceptual comprehension F = 11.89, p = .00
Bartlett's Test of Sphericity: χ^2 = 63.34, df = 1, p = .00
*$p < .05$

comprehension that were higher than those of students to whom the normal learning process was applied. Such findings concur with the idea of Khonchaiyaphum (2002) and Lapbunrueang (2000) who studied the comparison between the means of learning achievement and conceptual comprehension of a group of students treated with the learning process in accordance with Posner's approach of conditions for changing concepts and those of the group of students that had been taught normally and the researchers found that the former group had means that were greater than those of the latter group. Another reason for the experimental group having higher means than those of the controlled group is that the learning process in accordance with Posner's approach of conditions for changing concepts has been repetitively adjusted in accordance with the design-based research technique in order to suit the contexts of the students of the experimental group, whose capabilities vary and who like learning activities that are challenging with competitive ambience.

The study on the learning achievement and conceptual comprehension in the matter of organic chemistry in the subject of chemistry by implementing Posner's approach in accordance with the design-based research method of the students in the experimental group led to the discovery that the means of learning achievement and conceptual comprehension after the implementation of the designed leaning process were higher than those before the implementation of the learning process. This concurs with Posner's approach of the conditions for changing concepts that emphasizes having students change their concept during the learning process, which is the tactic to promote conceptual comprehension by Posner et al. (1982) who have explained that a major element to correct misconception is the teaching tactic or technique that each teacher applies to teaching, which includes various teaching and learning methods such as demonstration and practices, which are activities that challenge students to show their efficiency and capabilities, along with the various assessment techniques that allow teachers to monitor the thinking processes of their students. Such findings concur with the ideas of Penwong (2003), Changkwean (1998), and Wiyo (2008) who studied the results from the implementation of Posner's approach to changing students' concepts and discovered that the means of the learning achievement and conceptual comprehension after the learning were greater than the means before the learning.

Conclusion and Recommendation

In the course of this research work, nine misconceptions in the matter of organic chemistry of chemistry subject and the learning process that fit students' contexts were addressed in accordance with the design-based research method. The designed learning process was developed on the bases of Posner's approach of the conditions for changing concept. Implementing the designed learning process, teachers may design and adjust the process in accordance with the contexts of each particular group of students, which may be different from the students in the experimental group in this research because the students in this research had diversified capabilities and preferred challenging learning activities in the competitive atmosphere. The design-based research technique is flexible in accordance with the real contexts of the samples. The designed learning process would have been more successful if the one designing the process had had chances to work with experts or to exchange knowledge and ideas with other teachers and educational personnel. The success of the implementation of the designed learning plan was because the plan or process was implemented along with the assessment and evaluation of conceptual comprehension during the course of the learning, which helped teachers to understand whether the thinking processes of students led to the correct understanding or misconception. As for other studies and research works in the future, teachers should be aware of the design of teaching and learning processes that include diversified teaching methods because the diversity of teaching methods is a factor that Posner deemed to be important along with insertion of the conditions for changing the concept.

Conflict of Interest

The authors declare no conflict of interest.

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