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STUDENTS' CONCEPTIONS OF LEARNING USING ANIMATIONS

Nursamiha Awang Morsid, Sallimah M. Salleh, Masitah Shahrill*

Sultan Hassanal Bolkiah Institute of Education, Universiti Brunei Darussalam,
Bandar Seri Begawan, Brunei Darussalam

*Corresponding Author: masitah.shahrill@ubd.edu.bn

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Abstrak. Penelitian ini mengeksplorasi integrasi animasi dalam pelajaran yang dirancang menggunakan kerangka teknologi, pedagogis, pengetahuan konten (TPACK) untuk meningkatkan pemahaman konseptual siswa dalam proses difusi dan osmosis. Penelitian ini dilakukan di sekolah menengah yang melibatkan 22 siswa kelas 12. Data dikumpulkan dengan menggunakan penilaian osmosis dan difusi konseptual (ODCA), yang merupakan tes diagnostik dua peringkat yang diberikan sebelum dan sesudah pelajaran. Pelajaran dirancang menggunakan siklus penelitian tindakan, terintegrasi dengan matriks tpack. Ada empat siklus untuk mengatasi dimensi pengetahuan siswa, yang mulai dari berpikir tingkat rendah hingga berpikir tingkat tinggi (deklaratif, prosedural, skematik, dan strategis). Uji-t berpasangan sampel digunakan untuk menganalisis data dan temuan mengungkapkan perbedaan yang signifikan dalam pemahaman konseptual siswa setelah pelajaran animasi terintegrasi dilakukan. Intervensi ini berhasil sebagaimana dibuktikan dari ukuran efek yang besar, bersama dengan peningkatan frekuensi siswa yang memilih tanggapan yang benar dalam ODCA.
Kata Kunci: TPACK, animasi, pelajaran biologi, penelitian tindakan

Abstract. This study explored the integration of animations in lessons designed using the Technological, Pedagogical, Content Knowledge (TPACK) framework to enhance students' conceptual understanding in the processes of diffusion and osmosis. The study was conducted in a secondary school involving 22 Year 12 students. Data was collected using the Osmosis and Diffusion Conceptual Assessment (ODCA), which is a two-tier diagnostic test administered before and after the lessons. The lessons were designed using an action research cycle, integrated with the TPACK matrix. There were four cycles to address the students' knowledge dimension, which scaffolds from lower order thinking to higher order thinking (declarative, procedural, schematic and strategic). The paired sample t-test was used to analyse the data and the findings revealed significant differences in the students' conceptual understanding after the animation-integrated lessons were carried out. The intervention was successful as proven from the large effect size, together with the increased frequency of students having selected the correct responses in the ODCA.
Keywords: TPACK, animations, biology lessons, action research

INTRODUCTION

Technology plays an important part in people's life (Anshari, et al., 2017; Huda, et al., 2017), and technology-enhanced learning is one of the researched methods in education literature (Ali, et al., 2015; Matussin, et al., 2015; Finti, et al., 2016; Huda, et al., 2016; Huda, et al., 2017; Fan, et al., 2018; Moksin, et al., 2018; Ebil, et al., 2020). With the advancement in technology, computers have proven that they can provide effective teaching instructions and one method is by using animation in teaching and learning (Weiss, et al., 2002). An animation can be defined as a simulated motion picture that aids in the visualization of abstract processes (Meir, et al., 2005). Animations are effective in explaining complex concepts, to illustrate systems which cannot be seen via the naked eye in a visual context, and to enhance conceptual understanding of systems and processes (Weiss, et al., 2002). According to Weiss, et al. (2002), animations in teaching and learning function in five ways: (i) Cosmetic function which aims to make the instruction attractive; (ii) Attention gaining function which aids in capturing student's attention especially at the beginning of the lesson; (iii) Motivation function which can be used as feedback mechanism during lessons; (iv) Presentation function which supplements the teacher's instructional materials; and (v) Clarification function which provide conceptual understanding with visual means. Meanwhile, Hwang, et al. (2012) reviewed the use of animations in learning, and concluded that animations deliver better representations of dynamic concepts, assist in explaining complicated subject matter, and therefore facilitate students' learning. The visual nature of animations is considered to be the most common reason for it to be integrated in lessons in order to engage students in the classroom (Fisk, 2008). In short, animations are used in lessons to reduce students' cognitive load as well as an approach to overcome the language barrier (if any). However, animations may or may not reduce the cognitive load of students (Mayer & Moreno, 2003). According to the cognitive load theory, learning occurs when the conditions for learning supports the 'human cognitive architecture' (Paas, et al., 2010). The cognitive load theory is based on the assumptions of visual and verbal representations, limited capacity and active processing (Mayer & Moreno, 2003). This theory concerns how learners process complex and interactive information prior to experiencing meaningful learning (Paas, et al., 2010). When animations contain an overload of information, it can affect the cognitive processing of learners poorly where too much attention is given to the visual and verbal representations and less attention to make sense of the new information.

The teaching methods, which incorporated animations in the concepts of diffusion and osmosis can aid in the process of understanding (Sanger, et al., 2001), and with the help of animations, students were able to understand the processes of diffusion and osmosis at a particulate level. Several other researches also reported that animations do improve and enhance the processes of learning and understanding (Meir, et al., 2005; Soika, et al., 2010; Hwang, et al., 2012; Aksoy, 2013). Aside from the obvious findings of enhanced understanding, Zanin (2015) found that 80% of students that participated in a survey of science learning preferred lessons that were integrated with animations. This preference shows that students are inclined to engage in animation-integrated lessons, and encourages them to learn science. However, findings of other studies which have integrated animations in learning the concepts posed conflicting results, most of which are in line with the cognitive load theory. For example, a study conducted by Karlsson and Ivarsson (2008) observed that instead of enhancing understanding, the animations act as an antagonist of conceptual development. The reason for this could be due to the usage of an excessive amount of animations, which would be too distracting, and could pose a different outcome than it was intended for (Fisk, 2008; Aksoy, 2012). Similarly, in a study by Hübscher-Younger & Narayanan (2003), it was observed that the use of animations alone does not result in enhancing students' conceptual understanding, and their findings showed that animations can enhance conceptions using a constructive pedagogical approach, such as collaborative learning, in lessons. Therefore, this is where the technological pedagogical content knowledge (TPACK) can benefit the teaching and learning process using animations. The TPACK framework was developed based on Shulman's descriptions of how the interaction of technologies and pedagogical content knowledge can result in effective teaching (Koehler & Mishra, 2009). The framework is comprised of three main knowledge components and the interactions among them. The interactive components are represented as pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK).

There is no specific approach on how to incorporate ICT in education on order to achieve a perfect outcome (Koehler & Mishra, 2009; Masniladevi, et al., 2018). It is believed that the TPACK framework is powerful and has a great potential to be used in the research and development, particularly in the integration of ICT in education (Chai, et al., 2013; Salleh, 2013; Sarkawi & Salleh, 2016; Salleh, 2016; Huda, et al., 2017; Ebil, et al., 2020). On using the TPACK framework in ICT-integrated lessons, Archambault and Barnett (2010) observed that most teachers who participated in their survey thought that it was hard to use the TPACK framework in practice because of the different domains. Meanwhile, a study on teaching mathematics with TPACK found that teachers were able to integrate technology into lessons fluidly using the TPACK matrix (Felger & Shafer, 2016; Muhtadi, et al., 2018; Sukirwan, et al., 2018; Tatar, et al., 2018). This matrix was first introduced in a research on guiding pre-service teachers to use TPACK (Niess, 2008). The TPACK matrix clearly outlined the TPACK knowledge components and the students' knowledge dimension, which are declarative, procedural, schematic and strategic (Shavelson, et al., 2003; Niess, 2008). The student's knowledge framework was designed by Shavelson, et al. (2003) in an attempt to define scientific achievement. It is considered to be useful as it scaffolds the students' knowledge from lower order to higher order thinking skills. In this study, the TPACK matrix was used to organise and design the animation-integrated lessons. This study hypothesizes that animation can enchance students' conceptual understanding for the science topics investigated.

METHOD

This study aims to investigate how the integration of animations in lessons designed using a framework, which integrates teacher's Content Knowledge (CK), Pedagogical Knowledge (PK) and Technological Knowledge (TK) can enhance students' conceptions. Based on the TPACK framework, this study utilized an action research using the TPACK framework with mixed quantitative and qualitative methods to address the two research questions: What are the students' conceptions of the concepts before and after learning using animation? And how does using animation in learning the concept enhance students' learning?

The TPACK framework became the basis for designing the lessons and the cycles of Plan, Act and Reflect in the action cycle adapted from Lewin's Action Research Model (Dickens & Watkins, 1999). According to the Dialectic Action Research Spiral, in order to conduct an action research study, the four processes have to be followed: identify focus area, data collection, data analysis, and the development of an action plan. For example, if the first cycle succeeds, the study will continue to the second cycle. If however the second cycle does not succeed, the researchers will then reflect, redesign and redo the cycle again, before proceeding to the next cycle. The four cycles of intervention were based on the action research spiral of plan, act and reflect, and the TPACK matrix, which is adapted from Niess (2008). The intervention cycle was conducted in phases, according to the TPACK matrix. All the cycles were executed in a technology-enhanced, Inquiry-Based Learning (IBL) environment as follows:

1. The *Declarative* knowledge dimension: Focused on the knowledge of 'what'. This lesson stressed upon the definitions and basic components of the topic, e.g. the definition of Diffusion and Osmosis. The Engage, Explore, Explain, Elaborate, and Evaluate (5E) method of teaching were adopted for this cycle. The technology used are the Animation: GIF images from the Quiz: Kahoot! Application (refer to Figure 1).

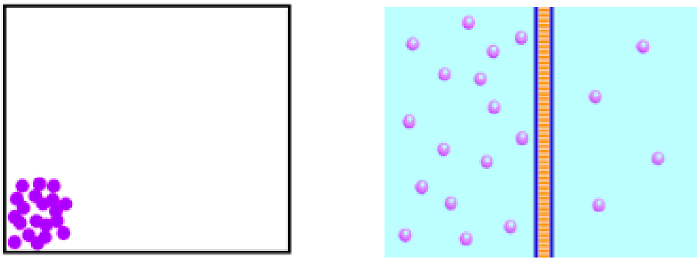

Figure 1. GIF images used in Cycle 1

2. The *Procedural* knowledge dimension: Focused on the knowledge of 'how'. There was a practical demonstration on the topic conducted by the teacher (the first author). Based on the knowledge gained from the first cycle, the students would be able to produce the knowledge pertaining to explaining how diffusion and osmosis occur, with reference to the practical demonstration. The Predict Observe Explain (POE) method was adopted for this cycle. The technologies used are the YouTube videos shown in Figure 2 (from https://youtu.be/272FEDPryzQ and https://www.youtube.com/watch?v=zuNMVzTeCtw).

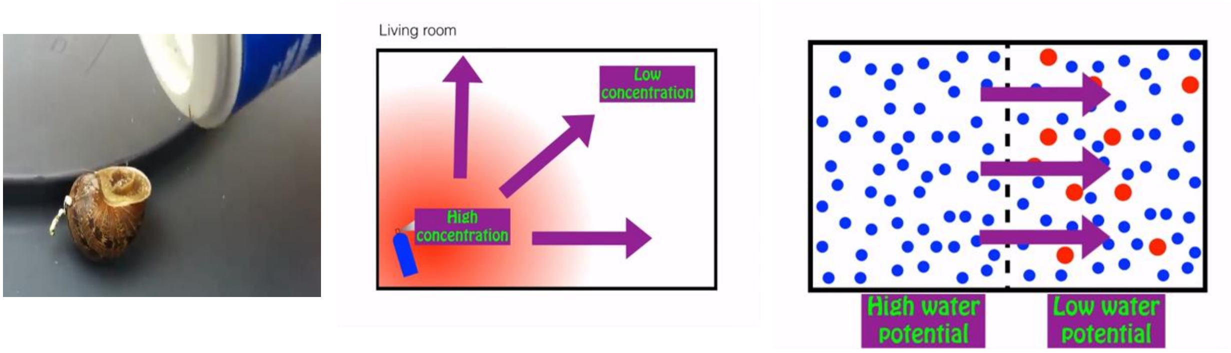

Figure 2. The videos used in Cycle 2

3. The *Schematic* knowledge dimension: This cycle focused on the knowledge of 'why', where it involved a discussion on experiments of the topic. Knowledge gained from Cycles 1 and 2 will assist the students to build on the knowledge of explaining why diffusion and osmosis occur. In this cycle, two videos of correct and incorrect information pertaining to the topic were purposely selected, and letting the students to do discussions. The technologies used are the YouTube videos shown in Figure 3 (from https://www.youtube.com/watch?v=LeS2-6zHn6M and https://youtu.be/uFV5co3OMdU).

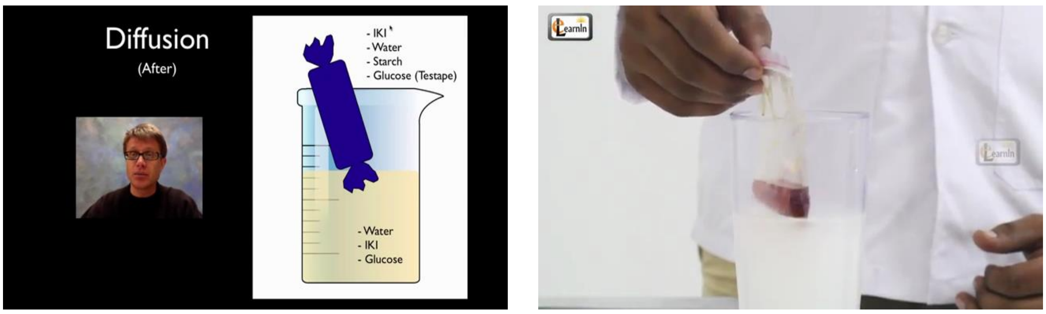

Figure 3. The videos used in Cycle 3

4. The *Strategic* knowledge dimension: Focused on the knowledge of 'when' and 'where'. In this cycle, the students would be able to use the knowledge gained from the previous cycles to design a collaborative science project presentation. For the technology part, the students have the freedom to choose any presentation apps or software.

The study was conducted in a secondary school in Brunei Darussalam with 22 Year 12 students (four males and 18 females). Similar to most school students in Brunei, the participants are considered as English as a Second Language (ESL) learner. However, unlike the other schools, these students were immersed in the Arabic school system from Year 5, and required to attend lessons in three languages (Malay, English, and Arabic). The test instrument was based on a modified version of the Diffusion and Osmosis Diagnostic Test (DODT) formulated and published by Odom (1995). The modified test, known as the Osmosis and Diffusion Conceptual Assessment (ODCA), was developed by Fisher, et al. (2011) and was evaluated, refined, and validated through consecutive test administrations to biology students in a public university. The test questions are aimed to assess students' understanding and reasoning of the concepts of diffusion and osmosis. The ODCA is a validated two-tiered multiple choice questions which consists of nine paired items (18 questions) covering the conceptual areas of the particulate and random nature of matter, the kinetic energy of matter, the process of Diffusion, the process of Osmosis, the diffusion of particles, and solute and solvent movement through a membrane (Odom, 1995; Fisher, et al., 2011; Oztas, 2014). The table of specification Fisher, et al. (2011) highlights three categories: Dissolving and solutions, Solute and solvent movement through a membrane, and Diffusion of particles. Additionally, the reliability of ODCA was at least 0.70 using Cronbach's alpha calculation (Fisher, et al., 2011). The DODT and modified DODT had been used in several studies and the split-half reliabilities reported in these studies were found to be above 0.70 (Odom, 1995; Meir, et al., 2005; Tomažič & Vidic, 2012). The first tier comprised of a content question with two to four answer choices, while the second tier comprised of four possible reasoning answers. The items will be scored correct if both the answers for the first tier and the reasons given for the second tier are selected correctly, and the item will be scored incorrect if the students select an incorrect response in either one of the tiers (Odom, 1995).

The 18 items of the ODCA was divided in accordance to the objectives of the TPACK knowledge dimension. In each test, there were three pairs of questions selected in order to match each of the lesson cycle objectives. The test for the last cycle, however, contained all the item categories of the ODCA. The design of the test administration has been summarised in Table 1. The pre and post-test results were used to measure the students' understanding and conceptions. The pre-test was given at the start of each research cycle to assess the prior knowledge of the students, and the post-test was given after the completion of the stages of the TPACK framework to measure and analyse the effectiveness of the intervention.

Table 1. Design of test items in the intervention cycles

Concepts Assessed	**Cycle 1**	**Cycle 2**	**Cycle 3**	**Cycle 4**
Dissolving and solutions			✓	✓
Solute and solvent movement through a membrane	✓	✓	✓	✓
Diffusion of particles	✓	✓	✓	✓

This study investigates the conceptual understanding of students in diffusion and osmosis. Therefore, to study the responses, the analysis were conducted by following three levels of accuracy as done by Tsai and Chou (2002): Correct conception: Both tiers are correct; Misconception: Only one tier is correct; and Incorrect conception: Both tiers are incorrect. The scores were then analyzed using Statistical Package for the Social Sciences (SPSS) paired sample t-test to find out if there is any effect of the intervention in this study on the conceptual understanding among the students. Prior to the quantitative data analysis, the gain scores for each cycle were tested for normality. The gain scores were calculated by subtracting the post-test scores from the pre-test scores. The assessment for normality was done to ensure that the data was suitable to be used in parametric statistical analysis.

RESULTS AND DISCUSSION

Altogether, there are five sets of the pre-test and post-test scores. We refer Cycles 2.1 and 3.1 to the original Cycles 2 and 3, and Cycles 2.2 and 3.2 to the redesigned cycles. The gain scores for the pre- and post-test scores were calculated and checked for normality using SPSS. This was done using the graphical methods, such as histogram and curve, skewness, and kurtosis. The assumptions for normal distribution include: The data was found to conform to the assumptions for normal distribution.

Table 2. Assessment for normality of the lesson cycles

Cycles	Skewness	Kurtosis
1	-.032	-.852
2.1	.000	.157
3.1	.167	-.753
2.2	-.172	.650
3.2	-.227	.022

Students' Conception of the Concepts Before and After Learning using Animations

The students' conceptions of the topic were measured with a three levels of accuracy (Tsai & Chou, 2002) using the data collected in the pre- and post-tests. The conception statistics were calculated and the frequency is represented as the percentage of students' conceptions as seen in Table 3.

Table 3. Percentage of students' conceptions

Item Numbers	Percentage of students' conceptions (%)					
	Correct Conception		Alternative Conception		Incorrect Conception	
	Pre	Post	Pre	Post	Pre	Post
1, 2	45.5	59.1	45.5	31.8	9.09	9.09
3, 4	9.09	36.4	81.8	63.6	9.09	0.00

5, 6	23.8	81.0	9.52	9.52	66.7	9.52
7, 8	18.2	52.4	45.5	28.6	36.4	19.0
9, 10	85.7	90.5	14.3	9.52	0.00	0.00
11, 12	50.0	71.4	31.8	4.76	18.2	23.8
13, 14	63.6	90.9	27.3	4.55	9.09	4.55
15, 16	86.4	85.7	0.00	4.76	13.6	9.52
17, 18	71.4	81.0	14.3	14.3	14.3	4.76

In addition, the gain score of the pre- and post-tests was also calculated and presented as the conceptual change in percentage in Table 4. It shows that the frequency of students having the correct conception prior to the intervention which ranges from 9% to 86%. With reference to the pre-test scores, more than half of the students were able to select both tiers of items correctly for five pairs of items (9/10, 11/12, 13/14, 15/16 and 17/18) out of the nine pairs in the ODCA. The items which portrayed the best scores (above 80%) are identified as the impact of increased temperature on the movement of molecules (pair 9/10), and the aspects of Brownian motion, where particles continue to move even if they are already evenly distributed in the container (pair 15/16). The other correct conceptions of other items were fairly satisfactory, and hence show that the students have partial understanding of the concepts of diffusion and osmosis.

Table 4. Percentage of students with correct conceptions

Item Numbers	Percentage of correct conceptions (%)		
	Pre-test	Post-test	Conceptual Change
1, 2	45.5	59.1	+13.6
3, 4	9.09	36.4	+27.3
5, 6	23.8	81.0	+57.2
7, 8	18.2	52.4	+34.2
9, 10	85.7	90.5	+4.80
11, 12	50.0	71.4	+21.4
13, 14	63.6	90.9	+27.3
15, 16	86.4	85.7	-0.70
17, 18	71.4	81.0	+9.60

After the intervention lessons were conducted, there is an increase in the frequency of students having correct conceptions in the ODCA. Overall, the results for the post-test scores are highly satisfactory where more than half of the class selected both tiers correctly for eight pairs out of the nine pairs question. This can be seen in Table 4, where every item covered in the ODCA gained an improvement of scores except for the items 15 and 16, with a negative conceptual change (-0.70%). However, a majority of the class had chosen the correct response (85.7%). It appears that a few students became confused after the intervention lesson, and answered the wrong response in the post-test. It could be that the students had the general idea of diffusion, but due to the confusion of the phrase used in the ODCA, they selected the wrong response.

The general trend of students having alternative and incorrect conceptions can be seen to decrease after the animation-integrated lessons were conducted (Table 3). There were three question pairs identified to have the lowest frequency of students having selected both tiers correctly, and they are the item pairs 3/4, 5/6, and 7/8. These results are consistent with the findings of Fisher, et al. (2011), where they showed that most students had alternative and incorrect conceptions for the three item pairs 3/4, 5/6, and 7/8. The alternative conceptions were identified, and the following discussion will include the excerpts extracted from the ODCA. The most prevalent question which had the highest frequency of students (about 90%) having alternative conception before the intervention lesson is the item pair 3/4 (Table 3). The results showed that even after the lesson, more than half of the students (63.6%) still held alternative conception (Table 3). The excerpts for this pair of alternative conceptions are:

Category: Diffusion of particles
3a: During the process of diffusion, particles will generally move from an area of (a) high to low particle concentration…
4a. …because crowded particles want to move to an area with more room.
4c. …because the particles tend to keep moving until they are uniformly distributed and then they stop moving.

Items 3 and 4 fall under the category of diffusion of particles. Reasons postulated for the incorrect conceptual understanding of items 3 and 4 include that the students were not familiar with dynamic equilibrium, and that students tend to use anthropomorphic concepts to answer this question. Dynamic equilibrium is the key state of diffusion, where it refers to no net movement of particles. Students might be confused with the sentence "stop moving" with no net movement (response 4c). The response 4a shows that students associate common sense with scientific concepts, and used anthropomorphic explanations: the need to move into an area in order to equalize the concentration of particles. The insignificance in the improvement of the conceptual understanding of this pair of items was deliberated and resolved by reviewing the lesson activity relative to the objective of items 3 and 4. The students were asked to explain how diffusion occurs when an air freshener was sprayed in a room, and the results are compiled and tabulated (see Table 5). All of the students' answers reflected their understanding about the movement of particles in diffusion. However, it can be seen that none of the students mentioned about 'dynamic equilibrium'. This confirms the findings and reasons explained in the above paragraph.

Table 5. Students' response in the class activity

Group	Explanations
1	The air freshener is being sprayed from one end of the room, air particles from it spreads from a region with higher concentration causing the person being closest to the air freshener to be able to smell the scent first, as the particles travels across the room to fill up available spaces, thus the furthest person is the last one to be able to smell the scent.
2	The air particles of the air freshener move randomly from the source, which has the higher concentration to the surrounding which has the lower concentration.

3	The person near the air freshener is at a region where the concentration is high.
4	When the teacher sprays the air freshener, the person closest to the teacher could smell it first and then the furthest person could smell it last. Therefore, the air particles spread throughout the room randomly because in the end all of the people in the room could smell it.
5	The person closer to the smell can sense a stronger smell than the ones further because the particles are not distributed evenly at the front, that's why the smell at the back is weak because the particles are distributed evenly.

With reference to Table 3, it can be seen that the greatest improvement in students' conceptions occurred for the item pair 5/6 with a 57.2% increase. This pair of items is identified as the second alternative conceptions held by the students prior to the intervention, and the excerpts are:

Category: Dissolving and solution
5a: If a small amount of table salt (1 tsp.) is added to a large container of water) and allowed to set for several days without stirring…the salt molecules will (a) be more concentrated on the bottom of the water…
6a. …because salt is heavier than water and will sink.
6c. …because there will be more time for settling.

Items 5 and 6 are concerned with dissolving and solution. The possible reason for students to have the alternative conceptions pertaining to this matter is that students think that salt is heavier than water, and that it will sink and settle at the bottom of the container. Common examples for diffusion are usually given in the concept of liquids, for example a coloured dye dropped in water. The students might be unable to associate their previous knowledge with the nature of this question, where it concerns the solid particle instead of liquid. Another reason might be because the students did not read the question carefully, because if they had, they would be able to see 'allowed to set for several days' which meant that the salt particles are allowed to set for a long period of time. The alternative and incorrect conceptions resulted from the inability of students to comprehend this statement, and answered for the instance when the salt was first introduced in the container. Hence, students might be confused with the concepts of gravity, and applied it into answering this question. The final item pair identified to have alternative conceptions (18.2%) in the study belonged to items 7 and 8, and this pair has the following excerpts:

Category: Solute and solvent movement through a membrane
7a: In Figure 1,...the water level in Side 1 will be higher than in Side 2...
7b: In Figure 1,...the water level in Side 1 will be lower than in Side 2...
7c: In Figure 1,...the water level in Side 1 will be the same height as in Side 2...
8a. …because water will move from high to low solute concentration.
8b. …because water flows freely and maintains equal levels on both sides.

The item pair 7/8 involves the movement of solute and solvent across a membrane. This category concerns the fundamental knowledge of osmosis. Failure in answering this pair of questions correctly reflects the lack of understanding of the basic concepts of osmosis and diffusion. The most prevalent incorrect response can be seen in response 8a, where it associates water molecules with the term 'solute concentration'. The students who selected that response showed that they had partial understanding of osmosis and solution chemistry terms.

Effects of Animations in Learning on the Students' Learning

The following results consisted of Cycles 1, 2.1 and 3.1. The scores of the pre- and post-tests were analyzed using the paired sample t-test in SPSS. The null hypothesis for this study was set to test the significant difference in the mean scores for each cycle. The p-value was set at .05; the null hypothesis of no difference will be accepted if the t-value is not significant at $p < .05$, and rejected if t-value is significant at $p < .05$. The null hypothesis obtained in this study suggests that there is no significant difference in students' conceptions of diffusion and osmosis before and after the animation-integrated lesson was conducted.

Table 6 shows the results of paired sample t-test, and it is revealed that there is a statistically significant difference in students' scores from Cycle 1 pre-test (M=39.36, SD=24.605) to Cycle 1 post-test (M=62.14, SD=29.757; t (21) = -3.364, p = .003) at $p < .05$. The null hypothesis is therefore rejected. However, there is no significant difference in the students' conceptions from Cycle 2.1 pre-test (M=51.50, SD=24.825) to Cycle 2.1 post-test (M=51.50, SD=28.755; t (21) = .000, p = 1.000), and also from Cycle 3.1 pre-test (M=60.05, SD=27.924) to Cycle 3.1 post-test (M=68.50, SD=20.234; t (19) = -1.165, p = .259) at $p<.05$. These results show that the null hypothesis of no difference for Cycles 2 and 3 is accepted. The effect size for Cycle 1 (.212), Cycle 2.1 (.000) and Cycle 3.1 (.034) were calculated following the Pallant (2010) formula. Based on Cohen's (1988) formula (.01 = small, .06 = moderate, .14 = large effect), the effect size in this study suggests a large effect size for Cycle 1, but both Cycles 2.1 and 3.1 had small effect size.

Table 6. Paired sample t-test for Cycles 1, 2.1 and 3.1

		Paired Differences					
		Mean Score	**Mean Differences**	**Std. Dev.**	**t**	**Sig. (2-tailed)**	**Eta Squared**
Pair 1	Cycle 1 Pre-test	39.36	-22.773	31.752	-3.364	*.003	.212
	Cycle 1 Post-test	62.14					
Pair 2	Cycle 2 Pre-test	51.50	.000	30.965	.000	1.000	.000
	Cycle 2.1 Post-test	51.50					
Pair 3	Cycle 3 Pre-test	60.05	-8.450	32.442	-1.165	.259	.034
	Cycle 3.1 Post-test	68.50					

Note: * significant at $p<.05$

Due to the insignificant difference and the small effect size in the students' conceptions before and after the intervention for Cycles 2.1 and 3.1, the lessons had to be redesigned and repeated for the post-test administration. However, because of time constraint, Cycles 2 and 3 were redesigned and combined into one final lesson. The final lesson, therefore, consisted of two lesson objectives, which aimed to achieve the second and third knowledge dimensions. The information acquired from the students' feedbacks was essential to design the repeat cycles. The striking comments on the previous cycles pertaining to Cycles 2 and 3 were about the level of difficulty of the lesson content, and also the nature of the animations used in the lessons. The objectives of Cycles 2 and 3 were combined to be in one lesson. Following the TPACK matrix, the design of the final lesson is shown in Table 7. The development of this lesson values the opinions from the students' questionnaire, in which the animations selected have clear narration with subtitles present, and the pedagogy employed was simple strategies involving group work and inquiry-based learning.

Table 7. Redesigned TPACK matrix for Cycles 2 and 3

TPACK Knowledge Dimension	Knowledge	Content	Pedagogy	Technology
Procedural	How	Explain how diffusion and osmosis occurs.	Inquiry based learning Collaborative learning	Animations from http://highered.mheducation.com/sites/0072495855/student_view0/chapter2/animation__how_diffusion_works.html and http://highered.mheducation.com/sites/0072495855/student_view0/chapter2/animation_how_osmosis_works.html Google Docs
Schematic	Why	Explain why diffusion and osmosis occurs.	Inquiry based learning	Animation: GIF images from GIF images from http://leavingbio.net/osmosis%20and%20diffusion.htm and http://mrphome.net/mrp/Membrane_Transport.html

After the final lesson was conducted, the post-test for Cycles 2 and 3 was administered to the students. The post-test scores collected was analysed using a paired-sample t-test to examine the impact of the intervention on students' scores on the pre- and post-test. Table 8 shows that there was a statistically significant difference in students' scores from both cycles: Cycle 2.2 pre-test (M=50.76, SD=25.189) to Cycle 2.2 post-test (M=69.95, SD=27.746; t (20) = -2.823, p =.010), and Cycle 3.2 pre-test (M=61.75, SD=27.216) to Cycle 3.2 post-test (M=86.75, SD=19.884; t (19) = -4.240, p = .000). This results shows that the null hypothesis of no difference is rejected. Meanwhile, the effect size for Cycle 2.2 (.166) and Cycle 3.2 (.321) were calculated using the Pallant (2010) formula. With reference to Cohen's (1988) formula (.01=small, .06=moderate, .14=large effect), the effect size in this study suggests a large effect size for both redesigned cycles.

Table 8. Paired sample t-test for Cycles 2.2 and 3.2.

		Paired Differences			t	Sig. (2-tailed)	Eta Squared
		Mean Score	Mean Differences	Std. Dev.			
Pair 1	Cycle 2 Pre-test	50.76	-19.190	31.147	-2.823	*.010	.166
	Cycle 2.2 Post-test	69.95					
Pair 2	Cycle 3 Pre-test	61.75	-25.000	31.147	-4.240	*.000	.321
	Cycle 3.2 Post-test	86.75					

Note: * significant at p<.05

These results show that there was an improvement of the students' conceptual understanding following the redesigned cycles. This successful intervention was also contributed from the knowledge acquired from the students' opinions. One reason was due to the selective process in the type of animations used (Masniladevi, et al., 2018; Azamain, et al., 2020; Batrisya, et al., 2020; Musa, et al., 2020; Phoon, et al., 2020). Initially, the type of animations used in the intervention cycle was not a pre-determined criterion. The redesigned lesson cycles used an animated video of diffusion and osmosis with clear narration, texts, labels, and the presence of English subtitles. The type of animations used was animated graphics showing the abstract processes. It was purposefully selected to overcome the students' language barrier and reduce their cognitive load (Chong, et al., 2018; Shahrill, et al., 2018; Shahrill, et al., 2018). The other comment on the previous cycles was on the difficulty level of the task given out. In the revamped Cycles 2 and 3, the inquiry-based learning technique to scaffold students' thinking skills was applied. Previously, the tasks given during the lesson comprised of complex procedures and required the students to think carefully. In the final lesson, the students were guided in an orderly manner, with instructions consisted of simple English Language vocabulary. The positive outcome of this study shows that this manner of teaching seemed to be conducive in enhancing students' learning.

CONCLUSION

Students' conceptual understanding of diffusion and osmosis is essential for the added understanding of life processes. These conceptions shaped their subsequent knowledge in the learning process, and can hinder the gaining of new knowledge when they have incorrect and alternative conceptions. The methods to enhance students' conceptions include that of the constructivist's way of learning, where the lessons are more student-oriented. This research addresses the knowledge gap in the literature where a framework is required to integrate the use of animations in the instructions immaculately. The hypothesis of this research is that animations can enhance students' conceptual understanding of the topics diffusion and osmosis. This research also believes that with great focus and attention on uplifting students' understanding, the TPACK framework can guide teachers and students to enhanced conceptions.

The ODCA used in this study proved to be successful in identifying students' conceptual understanding in diffusion and osmosis. The significance in the paired-sample t-test analysis, as well as the large effect size, of this research shows that animation is a suitable medium to enhance students' conceptual understanding of the two concepts. Even though there were studies that claim that the TPACK framework was a hassle to work with, the findings of this research shows that could be an advantage to gain students' attention and intention in learning. The TPACK matrix guides the teacher to plan the lessons well, and therefore aims to produce a favorable outcome. Students' feedback on using animations and other technologies in the lessons indicated a positive response on the TPACK framework.

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