The Development of an Augmented Reality Media Using Inquiry-Based Learning on the Topic of the Force and Motion Object

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Abstract: *The purposes of this research were to (1) create and assess the quality of augmented reality (AR) media using Inquiry-Based Learning (IBL) processes on the topic of "the force and motion object" of 9th grade students, (2) compare the learning achievement between pre and post learning from AR media using IBL processes, (3) compare learning achievement between the experimental group and control group, and (4) examine the satisfaction of students toward the AR media using IBL processes with the use of a posttest on the topic of "the force and motion object" of 9th grade students. The samples were consisted a total of two classes of 52 students in the first semester of the academic year 2016, Udomvittaya School, Thanyaburi district, Pathum Thani Province, Thailand. A class of 28 students was designated as the experimental group learning with AR media, another group was designated as the control group learning with traditional teaching method. The samples were selected by simple random sampling. The research findings were as follows: (1) AR media quality was high with the Index of Item-Objective Congruence (IOC) between .60 and 1.00, which was based on the hypothesis (2) the posttest score of learning achievement with AR media using IBL processes was significantly higher than the pretest score at the level of .05 (3) the posttest score of learning achievement of the experimental group was higher than the control group with the statistically significant difference at the level of 0.5 (4) the satisfaction of students learning from AR media using IBL processes was found at the high level. The results suggested that AR media using IBL processes on the topic of "the force and motion object" of 9th grade students could be used for instruction and learning.*

Keywords: augmented reality; inquiry-based learning processes; force and motion object; instructional media; instructional design

Introduction

Science subject is vital for every society because the integration between science and other fields can produce technologies, appliances, and other products. According to the Thai Bureau of Academic Affairs and Educational Standards (BAAES, 2008, p.1), science could assist humans to "develop thinking methods such as critical thinking, creativity thinking, analytical thinking, criticizing skills, researching for the knowledge, and be able to solve problems in a systematic way". The Thai 2008 core curriculum for basic education science learning substance group aimed to teach science with an emphasis on linking knowledge with the learning processes. Learners should develop important skills in researching and building a body of knowledge by using IBL processes and problem solving strategies. Moreover, teaching and learning processes should require learners to participate in learning activities and processes (BAAS, 2008).

Teaching, using IBL activities emphasizes learner-centeredness which enables students to seek knowledge and practice problem solving by themselves and in group as they become skillful in science subjects. The processes of inquiry steps were recommended by the Inquiry Page (2010) which consists of five steps: (1) Ask, (2) Investigate, (3) Create, (4) Discuss, and (5) Reflect. Moreover, the Institute for the Promotion of Teaching Science and

Technology (IPTST) (IPTST, 2003, pp. 219-220) introduced five steps of inquiry processes: 1) Engagement, 2) Exploration, 3) Explanation, 4) Elaboration, and 5) Evaluation.

The IBL activities are the continuous processes and assists learners to learn more because they bring different theories and principles into practice.

AR is a technology that combines the virtual world and real world together for people who have no chance of actually seeing the real situation. The combination of real and virtual objects remedies limitations of virtualization technology. Azuma (1997) divided the definition of AR into three features including: (1) a combination of real and virtual, (2) real time interaction, and (3) 3D technology. Currently, AR plays an important role in the daily human life, such as graphics, 3D shapes, and computer webcams. Smartphones and tablets are in common use and can be used for real time teaching and learning. Chiang, Yang, and Hwang (2014*)* found that AR can help learners pay more attention to their studies because it allows learners real time practice. Thananuwong (2013) stated that using AR technology both teachers and students enjoy learning because it is innovative and more interesting than traditional media instruction for Thai students.

The researchers have observed that some students only pay attention to the lecture at the beginning of the course with the PowerPoint presentations and they later get bored. This observation is consistent with the research of Suratruangchai, et al. (2005) which investigated the teaching circumstance and learning management, problems of teaching and learning management, and what was needed to improve about teaching and learning strategies. This study found that students lack intention, patience, and discipline in learning. While most faculty members used lecture-based teaching style, so they lacked varied teaching techniques and activities. Moreover, the evaluation focused more on memorizing rather than applying into practice.

To take advantage of AR technology, the researchers systematically designed a course using ADDIE Model. The model focused on the creation and development of teaching materials that encouraged students' participation in teaching and learning processes. The researchers carefully designed more efficient and effective learning processes. Furthermore, the IBL processes are applicable in many fields such as Science, Social Sciences, History, and Culture. Thus, in this study, the researchers applied an innovation with AR in educational technology field to develop and improve instruction and learning.

Purposes of the Study

1. To create and assess the quality of AR media by using IBL processes on the topic of "the force and motion object" with 9th grade students.
2. To compare pretest and posttest achievement scores of 9th grade students who learned with AR media by using IBL processes on the topic of "the force and motion object".
3. To compare the achievement of the experimental group who learned with AR media by using IBL processes and the control group who learned with traditional teaching style on the topic of "the force and motion object".
4. To study the satisfaction of 9th grade students toward AR media by using IBL processes on the topic of "the force and motion object".

Research Hypotheses

1. The AR media using IBL processes on the topic of "the force and motion object" with 9th grade students has high quality.
2. The achievement measured by the posttest scores of 9th grade students who learned with AR media by using IBL processes under the topic of "the force and

motion object" would be significantly higher than the pretest score at the level of .05.

3. The achievement measured by the posttest scores of 9th grade students who learned with AR media by using IBL processes on the topic of "the force and motion object" in the experimental group would be higher than the posttest scores of the students in the control group with a statistically significant difference at the level of .05.
4. The satisfaction of 9th grade students toward AR media by using IBL processes on the topic of "the force and motion object" might be high level.

Literature Review

Inquiry-based learning (IBL)

Kuklthau, Maniotes, and Caspari (2007, p. 2) stated that the IBL "…must be a process or procedure that was more than the search for answers, or answers to questions only, but would focus more on the processes of investigation, research, survey, tracing, and tracking, which was able to stimulate community involvement in the learning process because the learning caused by interaction in society."

The National Research Council (NRC) (1996) indicated that IBL is a set of relationships through which scientists and students ask questions about natural phenomena and investigate these various phenomena. This action would profoundly help students gain knowledge and develop understanding of concepts, rules and patterns, and various theories (p. 214).

The Ministry of Education Thailand (MOET) defined the scientific inquiry as "to search for knowledge in the scientific way using the scientific processes or other such as investigation, observation, measurement, classification, experiment, simulation model building, and searching for data" (BAAES, 2008, p. 105).

The Inquiry Page (2010) offered five steps of IBL as follows:

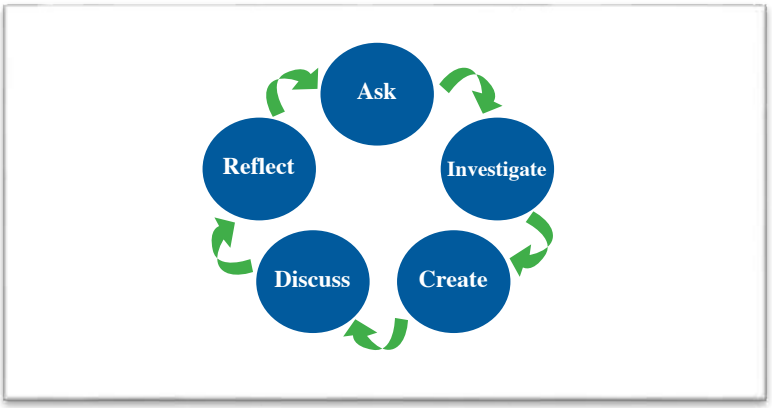

Figure 1: Five steps of inquiry-based learning model.
Source: excerpted and adapted from The Inquiry Page (2010)

1. *Ask:* This step begins with the curiosity questions, such as where do chickens come from? Where do eggs come from? Why does the moon change shape? After a period of learning, learners could find the answers or provide a new definition.
2. *Investigate:* This step is an actual practice step. It was called the "Investigation process" in which learners start to collect data by using experiments, observations, or interviews. If questions do not match with the purpose of the investigation, they need to be revised. The investigation processes are the opportunity for learners to participate in learning processes.

3. *Create:* This step is to synthesize and associate meanings for creating new creative knowledge where learners must create an idea, ideal perspective, or a new theory. Thus, the role of an instructor has changed from teaching to guiding. In doing so, it can open an opportunity for learners to build new knowledge.
4. *Discuss:* In this process, learners share their knowledge with fellow learners about his / her investigation. The discussion, summary, and exchange of experience are good examples of IBL processes.
5. *Reflect:* The reflection stage allow learners to review the questions for checking IBL processes and then summarize the results. If there was a problem at any stage it can be solved. This stage allows learners to examine, update, and revise by reflecting on the learning experiences in order to acquire deeper knowledge. The IBL procedures can assist learners to engage with the learning processes, stimulate learning, and allow proactive learning.

In conclusion, the five steps of IBL processes are a proactive learning model, from questioning to stimulate learners pursuing knowledge in different ways. Afterward, instructors would provide opportunities for learners to discuss and share some knowledge, ideas, and opinion with their classmates about what they have learned from the IBL processes since the beginning steps. In this case their classmates can provide some comments to revise and improve some issues and learners may need to study more on a particular topic.

Augmented Reality: AR

AR is a media that incorporates the virtual world and the real world by using a digital system (Azuma, 1997). Experts classified AR as having three features (a) a combination of real and virtual objects, (b) interaction in real time, and (c) the use of 3D technology (Azuma, 1997; Azuma et al., 2001).

El Sayed, Zayed, and Sharawy (2011) provided a different definition, where AR adds more information to supplement something missing in life by using virtual objects instead. Chen and Tsai (2012) supported this concept, and also mentioned that AR provides opportunity to interact with virtual objects, 2D, or 3D model to actually blend with the real world.

Thananuwong (2013) defined AR as a technology that combined the real world with a virtual world which overlays a three-dimensional virtual world onto the actual image of reality through the camera's digital tablet, smartphone or other device, and image display in real time.

In summary, AR is a media that combines virtual world and real world together by using a digital system to complement and add additional information for increasing the effectiveness of teaching and learning.

The application of AR

AR allows learners to learn such as the world and star, the digestive system of a cow, and even the zoo around the world. An image would be displayed similar to the real thing. It helps learners understand what they were interacting. This would not make learners feel bore when compared to what it was like the abstract or accompanying animation. For this reason, AR has become popular which it applied in many cases. For example:

Tourism: designers could present information that useful for travelers, including travel information such as exchange rates, maps, shelters, government buildings, restaurants, and tourist attractions.

Online trade: The pace of AR into e-commerce allowed customers to see virtual goods allowing potential customers to access additional background information to support their purchase decisions.

Education: AR has a role in education, not because the other AR allowed teaching was the most realistic. Although learners would not go into the actual situation or may not have a chance to actually touch, this was why learners excited to learn. Learners have seen which would differ from the usual textbooks. It was a three-dimensional image that could move like an authentic media (Tansiri, 2012).

Cheng (2017) found that using an AR book required a lower cognitive load on students. Students displayed more motivation, and more positive attitudes in learning. Moreover, Yilmaz, Kucuk, and Goktas (2017) found that most children were very happy with the activity and enjoyed using the interesting and fun AR picture books more than conventional books. Furthermore, Yoon, Anderson, and Elinich (2017) found that using AR can overcome the learning challenge of misconceptions about scientific ideas. That is using AR to investigate the science museum even in a short period of time, students gained greater knowledge over those students who did not use AR. The results of the interview also found that AR helped students to better understand science because it provided a better ability to visualize details and hidden information.

Instructional Design

The traditional format or ADDIE Model consists of five main steps with sub-steps:

1. *Analysis:* include problem analysis, learner analysis, content analysis, instructional analysis, identify instructional goals, and expert review and revision.
2. *Design:* consists of writing behavioral objectives, selecting evaluation and measurement tools, designing instructional strategies, selecting media and instructional material, and experts review and revision or formative evaluation.
3. *Development:* consists of developing evaluation instruction, developing instructional media and materials, developing learning management plans, developing guides for instructors and learners, and Experts review and revision or formative evaluation.
4. *Implementation:* consists of prepare presentation strategies, individual try out, small group try out, field trial, and expert review and revision or formative evaluation.
5. *Evaluation:* consists of data gathering or data collection, summative evaluation (Seels & Glasgow, 1998; Gustafson & Branch, 2002; Branch, 2009; Dick, Carey, & Carey, 2001).

ADDIE model was a traditional style, from which many variations have evolved from the original ADDIE model such as the following variations: Dick, Carey, and Carey (2001); Gagne et al. (2005); Morrison, Ross, and Kemp (2004); and Gustafson and Branch (2007).

Although ADDIE model would form a relatively complete and popular in the design of online teaching (Allen, 2006; Canbek, et al., 2011; Fresen, 2007; Soto, 2013;), many researchers have suggested that the design processes had to be relevant and appropriate for the environment and needs of teaching today, such as 3D technology and online teaching (Fresen, 2007; Kapp & O'Discoll, 2010; Irlbeck et al., 2006; Wang & Hsu, 2009) by mixing in some stages to suit the conditions of teaching and learning in the present. For instance, the Analyze Learners, State Standards and Objectives, Select Strategies, Technology, Media, and Materials, Utilize Technology, Media and, Materials, Require Learner Participation, and Evaluate and Revise (ASSURE) model was suitable for teaching in a learner-centered context (Sezer, Yilmaz, & Yilmaz, 2013) to maximize profitable relationship and the students.

Applying AR media with IBL processes model

This study used five learning processes of AR media using IBL activities: Engagement, Exploration, Explanation, Elaboration, and Evaluation which the IPTST (2003, pp. 219-220) provided steps of the force and motion object as follows:

1. *Engagement:* Teacher first defines learning objectives related to the topic of the force and motion object and allows students to search for them. The purpose of this step is to enable students to search for learning objectives, which are then continuously redefined throughout the five cycles of IBL processes. In this case it encourages students to create questions and identify learning objectives. When students have no strong interest teacher presented case studies or media in various ways to create and stimulate their interest but it should not lead or force them beyond their boundaries or grade level of appropriateness. It only facilitates or guides some necessary topics.

2. *Exploration:* In this stage, students must define learning objectives. Therefore, teacher has to provide background knowledge of learning objectives in the class and guide students to set learning scenario using mobile AR as a tool for learning content. Once a particular issue or question is understood, next step is to make a plan and to set guidelines for checking assumptions. Then, make a possible choice and plan for data collection. The teacher can guide them in data collection processes such as experiment, survey, and observation by using mobile AR.

3. *Explanation:* The data should be analyzed, interpreted, and summarized. After that they should be presented in various forms such as tables, graphs, and diagrams.

4. *Elaboration:* In this step students links new knowledge with prior knowledge for conducting further research. New knowledge applies to new situations or other contexts that help students build extensive knowledge.

5. *Evaluation:* This step evaluates learning processes to measure how much students have learned. Moreover, students can apply knowledge in other situations so that learning is continuous or uses the Inquiry Cycle.

In summary, the 5-step of IBL model of the IPTST (2003) is proactive learning processes as they encouraged students to use a variety of methods for gaining knowledge. Further, teacher allows students to apply new knowledge by sharing their knowledge with the classmates. By doing so, students may learn more from their classmates. Thus, they can improve or revise their understanding of a topic or issue, and, or search for more knowledge in order to gain a deeper understanding as shown in Figure 2.

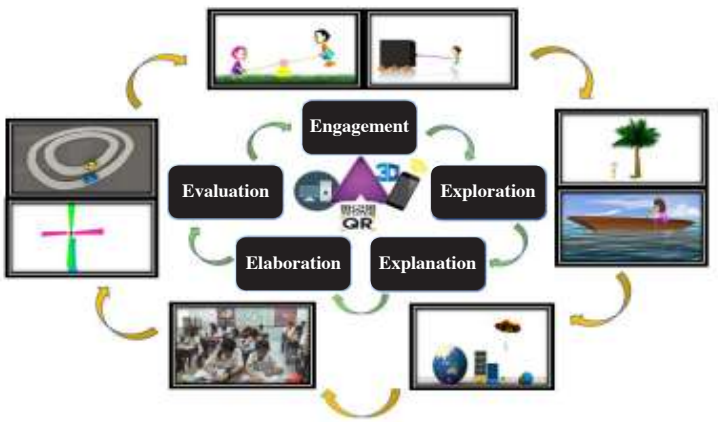

Figure 2: Applying AR media with IBL processes model
Source: Adapted from IPTST (2003) and researching activities

Research Methodology

Population and Samples

The population of this study was 108 of 9th grade students from four classes, at Udomwittaya School Prachathipat Sub-district, Thanyaburi District, Pathum Thani Province, Thailand. The students were organized by mixed ability classroom.

The samples of this study were selected by simple random sampling method using the classroom as a unit in a randomly selected for two classrooms include 52 students. The experimental group was 28 students and the control group was 24 students. The random procedures were as follows:

1. Selecting the samples with simple random sampling method for two classes.
2. Drawing for the experimental and the control group.
   2.1 28 students in an experimental group were taught by using AR media with IBL processes.
   2.2 24 students in control group were taught with traditional teaching method.

Research instruments

1. AR media with IBL processes
2. Pre and Post (Achievement) tests
3. Perception questionnaire toward AR media with IBL processes
4. Learning management plans

Data collection

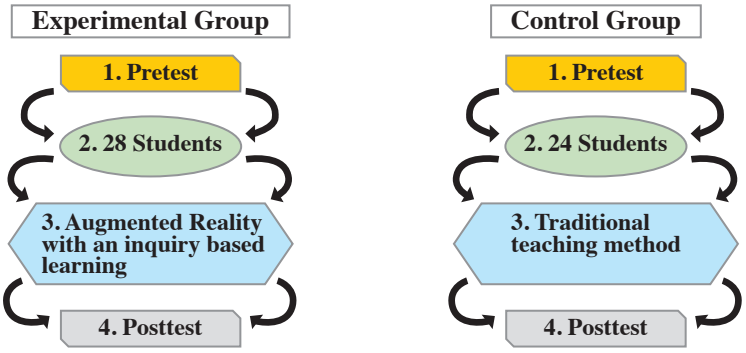

Figure 3: Data collection of the two groups

In this study, the researchers used an experimental model using a pretest and posttest for two groups of students.

True Experimental Designs and Pre-Test-Post-Test Control-Group Design Experimental One-Group Pretest - Posttest Design.

Group A	R	———	O	———	X	——— O
Group B	R	———	O	———		——— O

SOURCE: Adopted from Creswell (2009, p.161)

Figure 4: The Pre-Test-Post-Test Control-Group Design

To increase an understanding of the research process, the researchers plan more experiments like the Creswell (2009) as shown in the figure below.

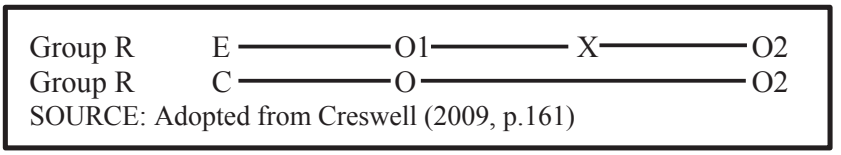

Figure 5: The Pre-Test-Post-Test Control-Group Design used in this study

The symbols used in the model experiment to convey meaning.

E	=	Experiment Group
C	=	Control Group
R	=	Random Assignment
O1	=	Pre-test
X	=	AR Media with an IBL
O2	=	Post-test

Data Analysis

The researchers analyzed the data as follows:

1. Find the Mean $(\bar{X})$ and Standard Deviation (S.D.) of pretest and posttest scores of the 9th grade students who learned from AR media with the IBL processes under the subject of "the force and motion object".
2. Find the Mean $(\bar{X})$ and Standard Deviation (S.D.) of the pretest and posttest scores of the experimental group and the control group.
3. Compare the average score on the pretest between the experimental group and the control group by using t-test independent sample.
4. Compare the average achievement posttest of the experimental group and the control group by using t-test independent sample.
5. Compare the average achievement pretest and posttest of the experimental group and control group by using t-test dependent samples.
6. Find the Mean $(\bar{X})$ and Standard Deviation (S.D.) of the students' satisfaction toward the AR with IBL processes.

Research Results

The results of the data analysis were presented as follows:

1. Create and design the quality of AR media by using IBL processes under the subject of "the force and motion object". The quality of AR media was evaluated by five experts in four aspects: (1) image and animation of AR media, (2) audio of AR, (3) instructiveness of AR, and (4) design of AR media. The IOC results showed values between .60 - 1.00, which could be consistent with the content and the hypothesis.
2. The comparison of learning achievement score between pretest and posttest of 9th grade students who learned from AR media by using IBL processes under the subject of "the force and motion object".

Table 1
A comparison of pretest score of experimental group and control groups

Learning Achievement	statistic		Independence Samples t-test		
	n	$\bar{X}$	***S.D.***	***t***	***df***	Sig.(2-tailed)
Experimental	28	10.79	1.424	1.042	50	0.302
Control	24	10.38	1.408			

* P <.05

Table 1 showed the average achievement scores of the experimental group compared to the control group. The results indicated that the pretest scores of experimental group ($\bar{X} = 10.79,\ S.D. = 1.424$) were higher than the pretest scores of control group ($\bar{X} = 10.38,\ S.D. = 1.408$) and the t-test was significant at .05 level. It was found that the learning achievement of the experimental group and the control group were not significantly different.

Table 2
A comparison of pretest and posttest scores of experimental group

Variables	statistic			paired t-test		
	n	$\bar{X}$	***S.D.***	***t***	***df***	Sig.(2-tailed)
Average Pretest Scores	28	10.79	1.424	-23.989	27	.001*
Average Posttest Scores	28	20.96	2.426			

* P <.05

Table 2 indicated that the achievement scores of the students who studied from AR media using IBL processes before and after learning had statistically significant differences at .05 level. The posttest scores were ($\bar{X}$ =20.96,S.D.=2.426) higher than the pretest scores ($\bar{X}$ =10.79,S.D.=1.424). Therefore, the achievement of the 9th grade students after learning from AR media was higher than before.

After the students learned from AR media by using IBL processes under the subject of "the force and motion object" with 9th grade students, the posttest scores were higher than the pretest scores with a t-test at -23.98 compared with the significant level of .05. Hence, this media assisted students to develop their knowledge and understanding on the topic of the force and motion object. This indicated that the experimental group students met their learning achievement which was consistent with the hypothesis.

Table 3
A comparison of pretest and posttest scores of control group

Variables	Statistic		t-test		
	n	$\bar{X}$	***S.D.***	***t***	***df***	Sig.(2-tailed)
Average Pretest Scores	24	10.38	1.408			
				-20.785	23	0.000*
Average Posttest Scores	24	16.38	1.245			

* P <.05

Table 3 showed that the pretest and posttest achievement scores of students in control group employing the traditional teaching method were at a statistically significant difference at the .05 level. The achievement of posttest scores ($\bar{X} = 16.38, S.D. = 1.245$) were higher than the achievement of pretest scores ($\bar{X} = 10.38, S.D. = 1.408$). The posttest achievement scores of students were higher than the pretest scores.

It could be concluded that Table 2 and 3 showed the achievement scores between the experimental group and the control group. The results revealed that the achievement after learning of the students in both the experimental group and the control group were high. The posttest scores of experimental group students was ($\bar{X} = 20.96, S.D. = 2.426$) higher than the achievement posttest control group ($\bar{X} = 16.38, S.D. = 1.245$).

3. Achievement results of the experimental group students who learned from AR media by using IBL processes and the control group students who learned with the traditional teaching method.

Table 4
A comparison of the achievement of experimental group and the control group

Learning Achievement	statistic		Independence Samples t-test		
	n	$\bar{X}$	***S.D.***	***t***	***df***	Sig.(2-tailed)
Experimental Group	28	20.96	2.426			
				8.363	50	.000*
Control Group	24	16.38	1.245			

* P <.05

Table 4 showed the average scores of achievement of the students in experimental and control groups. The findings found that the achievement after learning of the experimental group ($\bar{X} = 20.96, S.D. = 2.426$) was higher than the control group ($\bar{X} = 16.38, S.D. = 1.245$) and the different statistical Independence Samples t-test was at. 05 level. Therefore, the learning achievement of the experimental group after learning from AR media by using IBL processes provided students' achievement and the scores were higher than the control group using traditional teaching methods.

4. Results of 9th grade students satisfaction towards AR media by using IBL processes under the subject of "the force and motion object".

Table 5
The results of student satisfaction toward AR media

List	Satisfaction Level		
	$\overline{X}$	S.D.	Meaning
The content and implementation of AR media	4.33	0.34	High
Presentation graphics, colors, and sounds of the AR media	4.26	0.34	High
Assessment	4.28	0.40	High
Total	**4.29**	**0.28**	**High**

Table 5 showed the students satisfaction toward AR media using IBL processes. Overall, students' satisfaction was high ($\overline{X}$ =4.29,S.D.=0.280) which was congruent with the hypothesis. It was found that students were satisfied with AR media using IBL processes in the content and implementation of AR media ($\overline{X}$ =4.33,S.D.=0.34), followed by assessment ($\overline{X}$=4.28,S.D.=0.40), and presentation graphics, colors, and sounds of the AR media ($\overline{X}$=4.26,S.D.=0.34) respectively.

Discussion

Discussion from the results of the research, the achievement of learning with 9th grade students under the topic of "the force and motion object" using the IBL processes as follows:

1. The results of creating and assessing the quality of AR media by using IBL processes under the subject of "the force and motion object" with 9th grade students found that the IOC result was at .60-1.00 and this was consistent with the content. The results of AR media met the qualification of the design criteria because the content and the lessons were designed and analyzed systematically prior to design based on the five steps of ADDIE model including: 1) analysis, 2) design, 3) development, 4) implementation, and 5) evaluation which was the main systematic design.

Developing AR media it included problem analysis, learning objectives, design, and development. Moreover, content experts and media experts provided pre study development feedback and pre study trialing which were employed before using the AR in an authentic situation. This was congruent with the study of Tunya and Chaturanon (2008) which applied the ADDIE model in the development of online electronic science lessons using the learning activities based on the concepts of High/Scope instructional activity, starting from the analysis, design, development, implementation, and evaluation. The design of electronic lessons online was such a system and the achievement of students was higher than the normal classes students at the statistically significant level of .05.

2. The posttest achievement of an experimental group using AR media and IBL processes was higher than the pretest achievement. The level of statistical significance was at the .05 level because this media provided the opportunity for learners to practice by themselves on their own time and place based on the five stages of the IBL processes: (1) Engagement, (2) Exploration, (3) Explanation, (4) Elaboration, and (5) Evaluation (IPTST, 2003 pp. 219-220).

Using the IBL processes teachers began to generate students' attention to the lesson by using various strategies. As a result, students were interested in learning. After that, students have to study and find the answers and discussion in various problems or learning issues. The students were able to apply and build on their prior knowledge generate wider knowledge. The final step was to evaluate the different ways students learned.

Therefore, the application of AR media using the IBL processes was appropriate for instruction in the 21st century which corresponded to the scientific inquiry processes of the MOET that is, to use investigation, observation, and experiment, to search for knowledge (BAAES, 2008).

Another important strategy was the IBL processes that had efficiency and promoted cognitive learning as well. All this might be AR media using the IBL processes focused on the differences between individuals, student-centered, and a variety of learning processes. Learners can learn anywhere and anytime which they were able to review their lessons as they needed which was consistent with the concept of Kuklthau, Maniotes, and Caspari (2007, p. 2). They mentioned that the IBL processes would focus on the processes of investigation, research, survey, tracing and tracking, which stimulated community involvement in the learning process. In addition, they believed that learning came from the interaction.

Hence, integration of AR media with the IBL processes was suitable for teaching in the 21st century because it emphasized proactive teaching by using problem-based learning which this factor corresponded to the concept of (Price, 2001, cited in Chiang, Yang, & Hwang, 2014) which described that IBL as the processes with which the instructor would prompt students to create hypotheses, describe, and discuss the classification monitoring survey issues together to solve the various problems faced in everyday working life. Students who employed these processes would have the skills to interact in society with high level thinking skills (Price, 2001 cited in Chiang, Yang, and Hwang, 2014). Teaching in the 21st century learners were able to access content anytime and anywhere. The learners could bring any tools/equipment to study. Therefore, educational organizations must be able to provide and maintain technology to facilitate teaching and learning.

This was consistent with the Yu, et al. (2013) study which found that teaching English using mobile phones was not only convenient, but also it was very effective. Teaching English as a foreign language requires more time and effort in the design of learning management plans. Hsu's study (2017) found that when students used the self-directed or task-based AR educational game system they used lower mental effort and exhibited lower foreign language learning anxiety, while the learning effect was high. Today technology is increasingly pervasive in many areas, such as communication, education, and manufacturing so that the effective teaching of the modern digital technology should be used because it was convenient and portable. In addition, the results of this study were in accordance with the findings of Detsiri (2010), she studied *"The comparison of learning achievement on topic 'force and movement' science learning substance group for Matthayomsuksa 3 students using multimedia computer lesson and scientific teaching"*. The results found that the achievement of students who learned by multimedia computer lessons was higher than the pre-study and this was statistically significant at the .05 level.

3. The achievement of experimental group after studying with the AR media using the IBL was higher than the control group and it was statistically significant at the .05 level. The average score after studying with this media was at 20.96 whereas the average score of the control group was at 16.38. These scores showed that studying with AR using IBL allowed students to attain higher scores.

This is because AR media was designed based on the teaching pattern of the ADDIE Model. However, it should mix in some stages to suit the conditions and context of what and who is being taught. For instance, ASSURE model mixed with ADDIE model (Smaldino, Lowther, & Russell, 2012). This was appropriate for a learner-centered situation. Students showed more interaction and practice in gained more interaction and practiced in several steps, particularly "Require learner participation." Moreover, instructor needed to support

teaching and learning with technology and new media. Students must receive the evaluation before the formal assessment.

The achievement of the experimental group was higher due to the AR media. Consequently, the results of this study were consistent with the concept of AR offered by Azuma where AR is a kind of a technology that attempts to combine the augmented world and the real world together using digital tools (Azuma, 1997). Pejoska-Laajola, et al. (2017) also found that augmented video calls can improve work place learning in remote collaboration work environment by pointing at task objects and locations on the screen for other call participants to review.

4. Students' satisfaction with AR media with the learning processes of IBL under the topic of "the force and motion object" with 9th grade students was high. When considering each item, it found that the students were satisfied with AR media with the learning processes of IBL ranked at the top three as follows:

First, they were satisfied with the content and continuity of AR media in which the questionnaire number five showed that it helped students better understand content.

Second, question number 14 of the questionnaire of the assessment format showed that it was very clear and easy to understand.

Finally, the content and continuity of AR media where the scores were equal in two items: Item number 1 (the content was congruent with the indicators) and 2 (the content and the time were suitable). However, students were less satisfied with the background color.

In this point, the researchers designed and developed AR media in accordance with students' needs by using the five processes of the inquiry based processes. The teaching process is a quest for knowledge (IPTST, 2003).

These processes were created to generate students' interest and encourage the curiosity to learn deeply. Moreover, students were able to interact with one another as well as they can work together. The students also had opportunity to practice and reinforce their skills. This process is important as the instructor is responsible for process students easier and gives them a chance to present what they have discovered. This study was consistent with the findings of Detsiri (2010). She studied a comparison learning outcome between learning with computer multimedia and traditional science teaching "the force and motion object" in the learning area of science of the 9th grade students.

Detsiri's study (2010) showed that students were satisfied with computer multimedia was at a high level. In addition, the achievement of students who studied with computer multimedia was higher than the achievement of students who studied with traditional science teaching at a statistically significant level of .05.

The results of the satisfaction assessment and observation behavior of students, the students were satisfied with AR technology. For example, they preferred to learn with the AR media rather than the traditional instruction. During class, the researchers noticed that students were happy to see images in regular textbooks as an animation. Moreover, some students also asked for the AR media to study after class. The 3D images might motivate students' interest and understand the lessons much easier and faster than using textbook. Especially, the courses in science area, teachers should design them to illustrate more because it helped communicate more clearly abstract ideas. Hence, students may understand more quickly and allow multisensory intake of the subject being taught.

The results were consistent with research in the field of AR media that it not only improves academic achievement, but also motivate students to learn. This study was consistent with many researchers (Bujak et al., 2013; Cheng, 2017; Chiang, Yang, Hwang, 2014; Di Serio, Ibáñez, & Kloos, 2013; Jara et al., 2011; Joo-Nagata et al., 2017; Liu & Chu, 2010;Yilmaz, Kucuk, & Goktas, 2017).

Ibáñez et al., (2014) built an AR application for teaching and learning science concepts of electromagnetism. Their study showed that AR assisted students to achieve in learning objectives. It also provided immediate feedback. In addition, using AR with a smartphone could help students understand the content, and also encourage their interest in learning. This was consistent with the study of Chiang, Yang, and Hwang (2014) which found that the use of mobile technology combined with AR not only improved learning efficiency, but also encouraged students to learn digital technology as well. This might be due to the use of AR, which allows students to see still images, animation, and hear audio. Consequently, the students were very satisfied.

This study is also consistent with the concepts of Srifa (2013) in which he gave a definition of Aurasma that was an application for creating AR media and suitable for portable computer media that use, IOS and Android operating systems. A special feature of Aurasma is an intermediary for linking reality and the world of AR. The presentation form of media could see, control, and touch screen as still images, animations, sounds, and link to other Websites.

Suggestions for further practice as follows:

1. Before teaching the lessons, instructors must provide students both experimental and control groups to learn basic skills of using AR media. If some students were not proficient in the use of media technology, it might be an obstacle to the students' efforts to achieve the learning objectives.
2. The AR media must be appropriate for students.
3. The instructors should prepare and ensure that ongoing network connectivity for smartphones or portable computer were in working order to facilitate learning.
4. The instructor must choose suitable learning model or learning theory.

Suggestions for further research

1. A comparative study should be conducted to compare achievement with other teaching methods and other classes to find a suitable and appropriate class, media, model, and theory.
2. The media should be created to other forms of AR for applying in other courses.

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