Chapter #

STORY-BASED VIRTUAL EXPERIMENT ENVIRONMENT

Ming-Xiang Fan[1], Rita Kuo[2], Maiga Chang[3], and Jia-Sheng Heh[1]
[1]*Dept. of Information and Computer Engineering, Chung-Yuan Christian University, Taiwan*
[2]*Academic and Industrial Research Centre, Knowledge Square, Inc., Taiwan*
[3]*School of Computing and Information Systems, Athabasca University, Canada*

Abstract: Science education is important for students developing critical thinking skills. How to engage students in science learning becomes an important issue. This research aims to design a virtual laboratory for students practicing Science Process Skills. Moreover, the virtual laboratory uses story to raise students' learning motivation and uses a problem solving procedure to navigate students while solving scientific problems. To verify the usefulness of the virtual laboratory, this research has conducted an experiment with 31 grade-10 participants. The experiment results show that students believe the virtual laboratory is useful for them in learning Physics. Since students' past physics grades do not influence their intention of using the virtual laboratory, the story-based virtual laboratory can help both of low and high academic students in science learning and assist them establish their science process skills.

Key words: Science Education, Science Process Skills, Model for Problem Solving Activity, Virtual Experiment, Virtual Laboratory, Storytelling.

1. RESEARCH MOTIVATION AND CONTRIBUTION

Laboratory plays an important role of science education for engaging the processes of investigation and inquiry (Hofstein & Lunetta, 1982; Hofstein & Lunetta, 2004). Many teachers focus on improving students' high-stakes assessment performance in terms of listening to lecture and memorizing the facts (Banilower, Cohen, Pasley, & Weiss, 2008). Students might have lower

interests in learning science over time because of the boring lessons. Digital games could be a potential solution of increasing students' motivation in science learning (Honey & Hilton, 2011).

Digital games are popular in the modern society. In United States, there are more than 180 million people playing digital games for more than 13 hours per week (McGonigal, 2011). To adapting the teaching methods for the students grown up with games, Prensky (2001) has suggested that digital games could be used as educational tools. Evidences show that games could enhance students' learning motivation (Cheng, Kuo, Lou, & Shih, 2012; Yang, Chien, & Liu, 2012). Narrative context, goals, and rewards are important factors to attract students playing educational games (Dondlinger, 2007).

This research aims to design a virtual laboratory, called Virtual Experiment Environment, which combine the gaming factors and the virtual experiment to engage students in science learning. To reach the goal, the skills students need to learn from the virtual laboratory are considered. Moreover, to make students learn particular skills in the virtual laboratory, automatic navigation steps generation are designed.

This research first introduces important educational theories in science education in Section 2. Section 3 designs the story-based virtual experiment environment. The system is introduced in Section 4. Section 5 describes the research hypotheses and the experiment design. The collected data is analyzed and the findings are discussed in Section 6. Section 7 concludes the research and talks the possible future works.

2. LITERATURE REVIEW

2.1 Knowledge Structure

Knowledge structure is used for presenting the relationships among knowledge objects (Merrill, 2000). It can be used for knowledge management (Cayzer, 2004; Liu & Lee, 2013), misconception diagnosis (Chen, 2011; Chang, Chiu, Lin, & Heh, 2003), and item generation (Gierl, Lai & Turner, 2012; Kuo & Chang, 2009) in the area of advanced learning technology. Concept map, mind map and conceptual diagrams are knowledge structures which are widely used for knowledge construction and sharing (Eppler, 2006).

Wu and colleges (2008) have designed a context-awareness knowledge structure which has successfully been used to generate mobile learning activities (Lu, Chang, Kinshuk, Huang, & Chen, 2011). The context-

awareness knowledge structure is a three-layer structure, including the domain, concept, and object layers.

- Domain Layer: stores and presents the relationships among knowledge domains, such as Physics or Chemistry. It can also present the locations for mobile learning in the authenticate environments such like museums.
- Concept Layer: organizes the concepts related to the domain knowledge in hierarchical form. Take Figure 1 for example, the concept "kinetic energy transfer to potential energy" is a type of "kinetic energy conservation", so the "kinetic energy transfer to potential energy" is the child-node of the concept "kinetic energy conservation".
- Object Layer: stores the objects which particular domain knowledge in the concept layer may apply to. For example, the "bullet" is the object which can be used for explaining both of "motion with constant velocity" and "kinetic energy transfer to potential energy" concepts, is also related to the "velocity" and "height" Physics quantities while explaining those concepts.

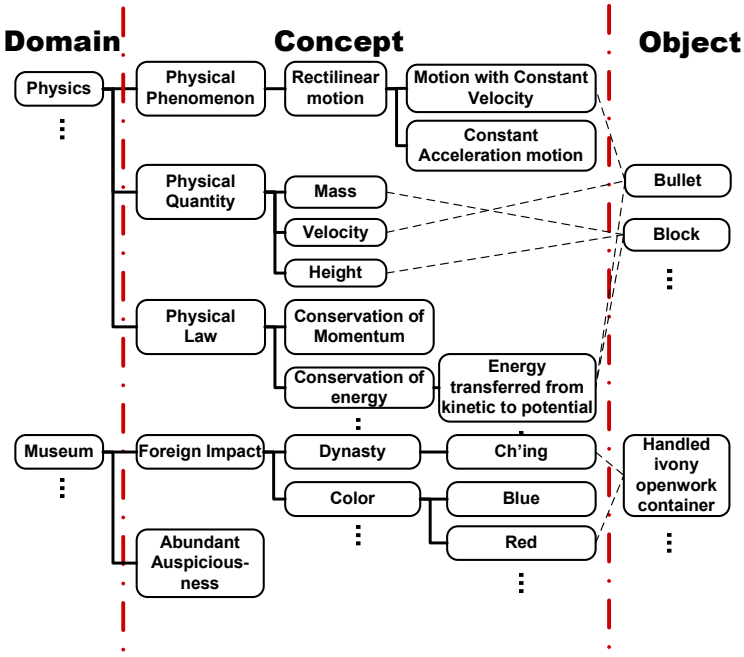


Figure 1. Example of context-awareness knowledge structure.

Knowledge structure is used for storing the science concepts in this research. Most of these concepts are declarative knowledge. This research

needs to further investigate what procedural knowledge students may need to learn in the virtual laboratories.

2.2 Science Process Skills and Virtual Laboratories

Scientists use science process skills to investigate the questions they met (Funk, Fiel, Okey, Jaus, & Sprague, 1979). Science process skills can help students form logical thinking (Koray & Koksal, 2009) and develop cognitive functions (Ozgelen, 2012). National Research Council (2009) also suggests that having science process skills should be one of science education goals.

Science process skills can be separated into basic and integrated science process skills. Basic science process skills are essential skill set in science investigation process, such as observation and classification. Integrated science process skills are skills used in high level problem-solving process; for instances, making hypotheses and analyzing collected data. Table 1 lists the science process skills proposed by Funk and colleagues in 1979.

Table 1. List of science process skills (Funk, Fiel, Okey, Jaus, & Sprague, 1979).

Basic Science Skills	Integrated Science Process Skills
• Observation	• Identifying Variables
• Classification	• Constructing a Table of Data
• Communication	• Constructing a Graph
• Metric Measurement	• Describing Relationships between Variables
• Prediction	• Acquiring and Processing Data
• Inference	• Analyzing Investigations
	• Constructing Hypotheses
	• Defining Variables Operationally
	• Designing investigations
	• Experimenting

Besides using traditional laboratory to train students' training science process skills, educators start to use technology to improve laboratory activities in science education. There are four major technologies applied in laboratory activities, including microcomputer-based laboratories, simulation/virtual reality, remote laboratories, and augmented reality (Chen, et al., 2012). Considering the limitations of space, time, and budget, this research applies interactive simulation to develop the virtual laboratory environment.

Interactive simulation has been widely used in science education. Fan and Geelan (2012) have pointed out that interactive simulation has four major benefits for science education, which are sparking students' motivation (Tambade & Wagh, 2011), supporting students' conceptual development (Fan & Geelan, 2013), engaging students' inquiring skills (Mustafa & Trudel,

2013), and realizing scientific discourse (Nichols, Hana, & Ranasinghe, 2013). However, most of teachers are unfamiliar with programming and have difficulty to build their own interactive simulations for their courses (Sved, 2010).

Easy Java Simulation (EJS) is one of the authoring tools for non-programmers, such as teachers, to create interactive simulations (EjsWiki, n.d.). Take Physics for example, researchers use EJS to teach harmonic motion, collision, geostationary orbit, etc. (Wee, 2010). Hwang and Esquembre (2003) also have built more than 80 simulations for Physics phenomena. This research uses the simulations made by Hwang and Esquembre (2003) in the proposed virtual experiment environment.

2.3 Virtual Experiment Environment

Though the use of interactive simulations in virtual laboratories reduces the cost, researchers have found that it also has limitation on supporting the planning and designing activities such as asking students to identify or manipulate variables of a Physics phenomenon (Chen, et al., 2012).

Kuo and colleagues (2000) have designed a virtual experiment environment which takes the model for problem-solving activity (Gott & Murphy, 1987; Welford, 1986) into its design in order to guide students solving science problems. Each stage in the model of problem-solving activity helps students practice different science process skills. Figure 2 shows the process that students doing experiment in the virtual experiment environment and the science process skills that they are practicing at different stages.

At Stage 1(a), problem generation and perception, students see an animation in the beginning. They need to identify what kind of scientific problems the animation represents. Students can practice their observation and classification skills. Next, students need to find the independent and dependent variables in the identified problem at Stage 1(b). Students can practice their skills in terms of identifying variables and constructing hypotheses.

After the variables are identified, students can choose which apparatus, such as scale or timer, they need to use for doing the experiment at Stage 2. They can practice their skills in terms of deciding what they need to observe (such as time or weight), considering how to measure it (such as the use of timer or scale), and constructing the relationships among variables. At Stage 3, students have to choose which apparatus is suitable for a certain situation in the experimental process. For example, students have to pick-up the scale with proper minimum unit (such as 1/4 inches or 1/8 inches) for measuring

the distance traveled by the ball. They can practice their skills of experimenting and metric measurement at this stage.

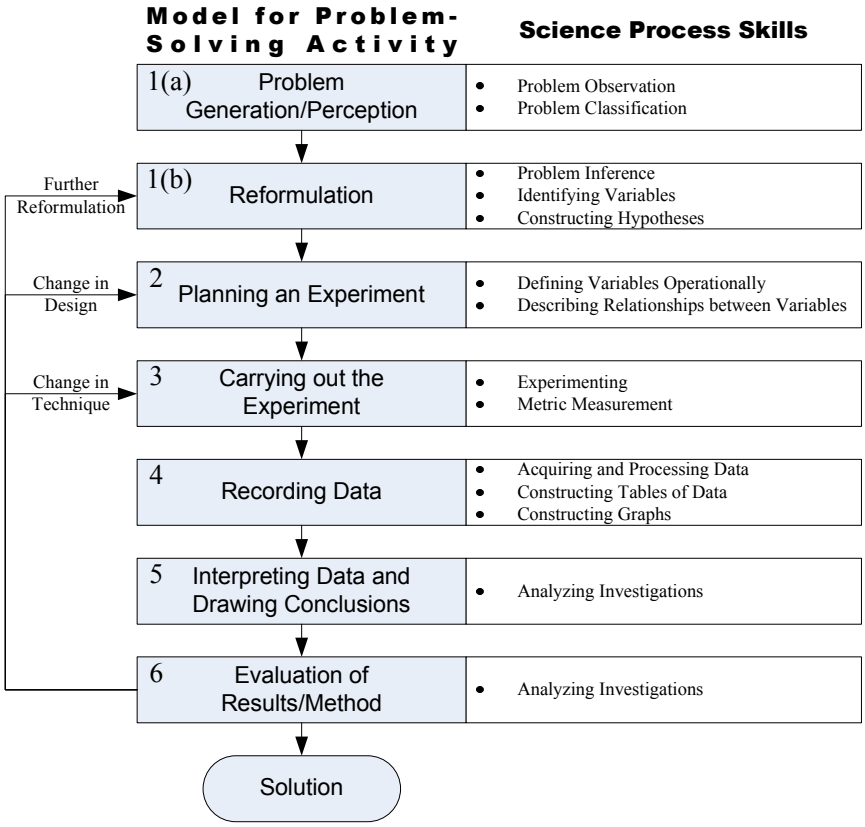


Figure 2. Students' experiment flow in virtual experiment environment

At Stage 4, students need to collect the data in various forms, such as table, graph, etc. Acquiring and processing data, constructing tables of data, and constructing graphs are the skills they could learn at this stage. With the collected data, students can interpret the experiment results and make conclusion accordingly, at Stage 5. They can practice their skills of analyzing investigations at this stage.

When students can't find the conclusion at Stage 5, the collected data might be inadequate for solving the problem. Students need to assess the methods and refine the experiment process at Stage 6. They can redefine the independent and dependent variables, choose other apparatuses, and use different techniques for data collection. Analyzing investigations is the skill they can practice at this stage.

3. PROPOSED METHOD

3.1 Story-based Virtual Experiment Environment

This research integrates story element into the virtual experiment environment proposed by Kuo et al. (2000). When students use the system, the system first prompts a story and asks students to solve the problem involved in the story. For example, students role play an adventurer in a scene of the story, where they encounter a valley and have to find a way to cross the valley by using a vine to swing to the other side which is higher than the cliff at this side (as Figure 3 shows). Students are at Stage 1(a) of the model for problem-solving activity at this moment.

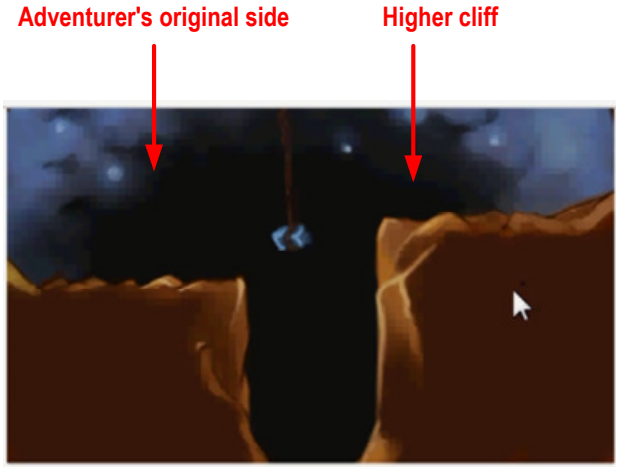


Figure 3. Scenario of adventurer encountering a valley.

Students then may make a hypothesis to solve this problem. For example, students can assume that when the adventurer runs faster, he or she may swing higher and reach the higher cliff at the other side of the valley. To verify the correctness of the hypothesis, students can choose one of the Java simulations (as Figure 4 shows) developed by Hwang and Esquembre (2003) to preview the correspondent follow-up story scene when their assumption is applied.

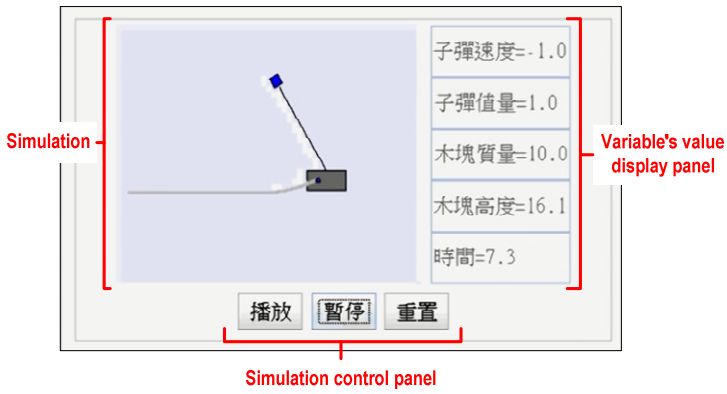


Figure 4. Snapshot of the Java simulation (Hwang & Esquembre, 2003).

Next, they have to find out which object in the story scene (such as the adventurer) is the corresponding object in the Java simulations (such as the bullet in a shooting simulation) as Figure 5 shows.

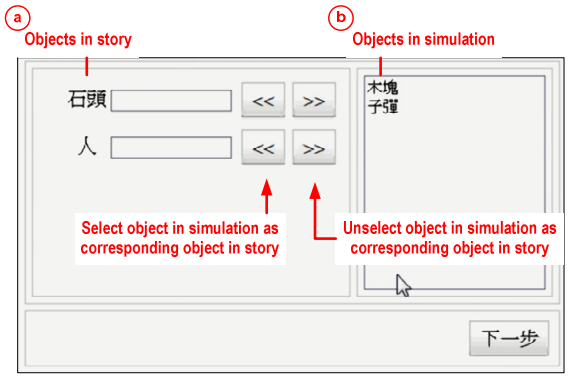


Figure 5. Students need to match the objects in the simulator to the objects in the story animation.

They also need to consider which variables (such as mass or speed) they may need to operate and to observe in the simulation. Figure 6 lists the physical quantities the chosen objects in the simulation have, such as speed, mass, friction, etc. Students can pick-up the physical quantities from the right hand side and move them to the left hand side so the particular values can be observed and manipulated later. Students are at Stage 1(b) of the model for problem-solving activity while doing this.

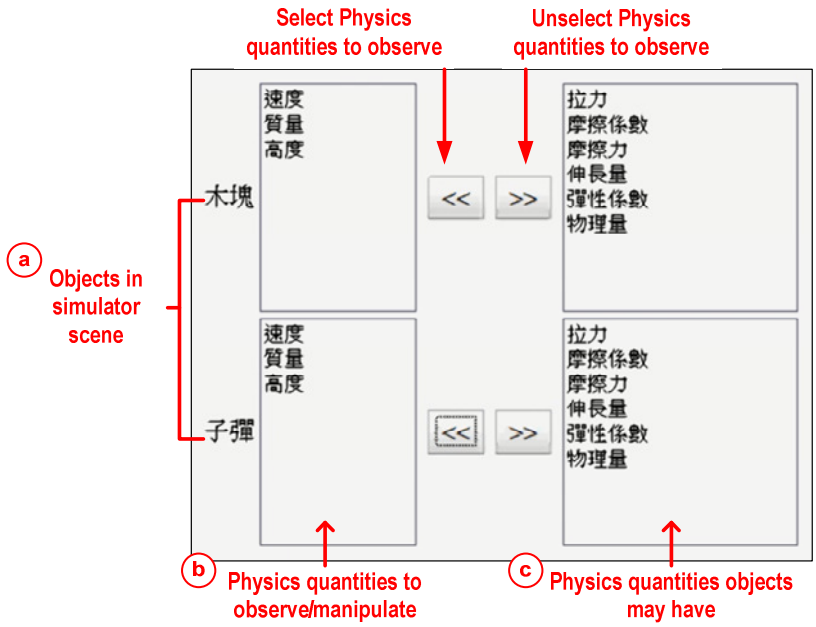


Figure 6. Students need to consider which Physics quantities they would like to observe or control in the experiment

At Stage 2, students need to consider what independent variable (which they need to manipulate), dependent variables (which they want to observe), and control variables (which are constant) are. In the above-mentioned story scene, students may think the running speed of the adventurer is an independent variable and the height that the rock can reach when it swings to the other side is the dependent variable. In Figure 7, the variables selected from previous step, in Figure 6, are listed on the right hand side of the screen. Students can choose any of them and assign them to one of the independent, dependent, and control variable(s) blocks to complete the experiment plan.

Next, students run the simulation by adjusting the values of the independent variables and record the values of the dependent variables via observation. As Figure 8 shows, students control Java simulation (in area ⓐ) via changing independent variable's value (in area ⓑ) and read the dependent variables' values (in area ⓒ). The recorded data is displayed in area ⓓ. When they do so in the virtual experiment environment, they are at Stage 3 and 4 of the model for problem-solving activity.

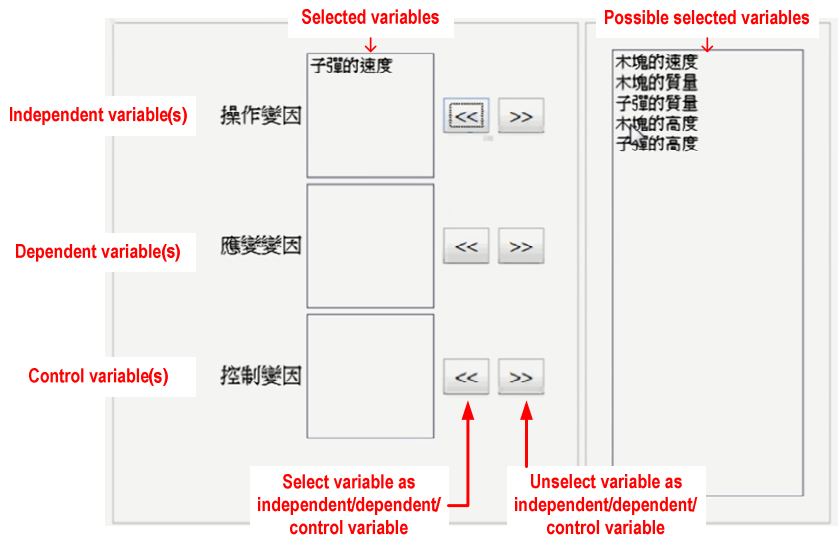


Figure 7. Students need to select variables listed in the "Possible selected variables" block and click "<<" buttons to assign the chosen variables to independent, dependent, or control block.

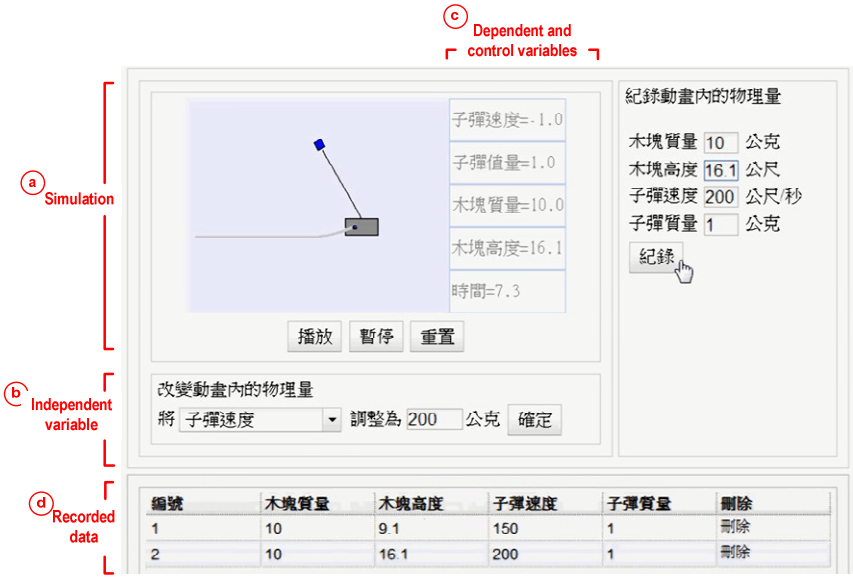


Figure 8. Students run Java simulation (Hwang & Esquembre, 2003) and record values of dependent variables via observation.

After the experiment data is collected, students can examine the data and interpret the relations between the independent and dependent variables as they are at Stage 5. In Figure 9, students can draw a graph according to the data recorded from the previous stage. Students also need to figure out which type of relation between independent and dependent variables have, such as positive and negative correlation. At the end of the experiment, students need to assess the experiment results and to think whether or not the results confirm the hypothesis they made earlier. If the hypothesis is not supported by the results, students can go back to previous stages to refine their experiment design.

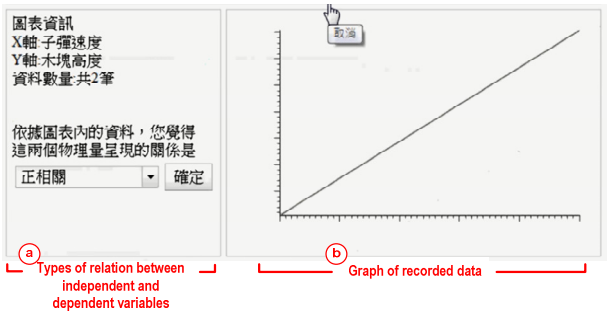


Figure 9. Students observe the graph of recorded data and figure out the relation between the independent and dependent variable.

3.2 Story-Based Context-aware Knowledge Structure

To automatically generate story and experiment scenes for each stage of the stages of model for problem-solving activity, this research designs a story-based context-aware knowledge structure to store the concepts in the scenes. The knowledge structure is modified from the context-awareness knowledge structure proposed by Wu and colleagues (2008). There are four layers in the knowledge structure as Figure 10 shows.

The first layer is domain layer, stores the domain that the virtual experiment environment has experiments for students doing, such as Physics and Chemistry. The second layer is concept layer, stores the domain relevant concepts in a hierarchical structure. Taking Physics domain as example, the concept layer has four major concepts:

- Physical Event: is the main concept in the story and experiment scene, such as object collision.
- Physical Phenomenon: stores the physical phenomenon students can observe. For example, in rectilinear motion, an object may move in constant velocity (i.e., the phenomena of motion with constant velocity);

when the object hits on another object hanging on the string, the pendulum movement may happen.

- Physical Quantity: is the physical attribute that an object has, such as its mass, velocity, acceleration, etc.
- Physical Law: is the principle of how physical quantities change in a class of phenomenon, such as Newton's second law and the law of conservation of energy (e.g., energy transferred from kinetic to potential).

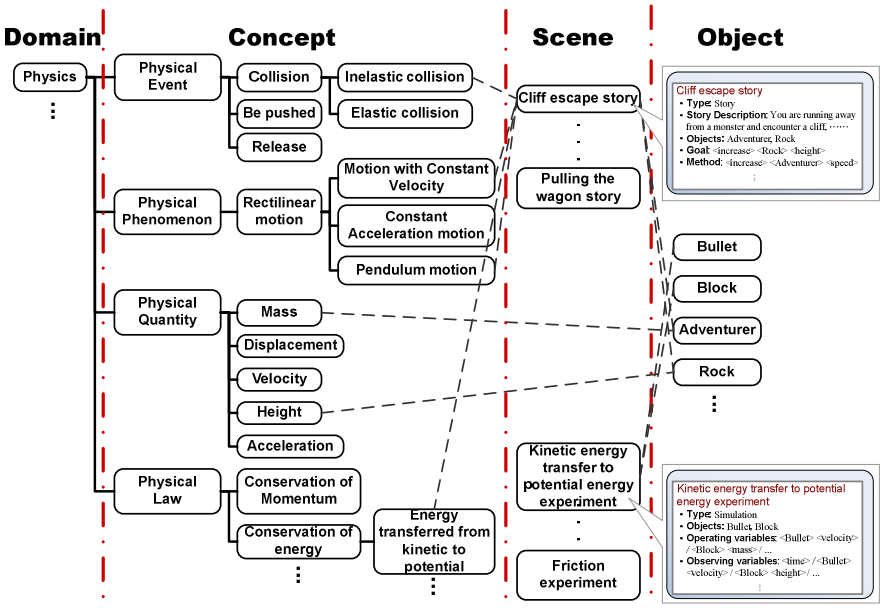


Figure 10. Story-based context-aware knowledge structure example in Physics

The original third layer, object layer, proposed by Wu and colleagues (2008) is divided into two layers – scene layer and object layer – in this research. The scene layer stores the information of the story and its scene. Take "cliff escape" story scene as example, the node has a story description label which is used for explaining to the students the scene in text; an object label which is used for associating the required objects in the object layer; the goal label which is used for the system to know what dependent variables and how their values should change to for solving the problem; and, the method label stores the correspondent independent variables and how their values should change to for making the dependent variables' values solve the problem.

4. THE SYSTEM

A Physics example of energy transferred from kinetic to potential is demonstrated in this section. In the beginning, students can choose "Cliff escape" story to start their learning as Figure 11 shows.



Figure 11. Students read the story description (in area ⓐ) and determine how to solve the problem. In this case, students think the goal of the problem (in area ⓒ) is *increasing rock's height* and decide to *increase adventurer's speed* to reach the goal (in area ⓑ)

The upper left of the screen shows the narration of the story animation that students can see at the upper right of the screen: *You are standing near a cliff and trying to reach the opposite side of the valley, which is higher than this side. Look! A rock is tied by a vine in the middle of the valley. Maybe you can jump on the rock and swing over to the other side. However, the other cliff is a little bit higher. How to swing over to the other side of the valley successfully?*

In the bottom of Figure 11, students need to make a hypothesis about how to solve the problem. In this case, as the goal label in the cliff escape scene node stores, the goal of the problem in this story is to *increase the rock's height* when it is swung to the other side of the valley; the method to reach the goal is to *increase adventure's speed*. Students can choose the objects and its physical quantities from the drop-down list to make their hypothesis.

After making the hypothesis, students can select which simulation they would like to use to verify their hypothesis. They could watch the simulations and consider which simulation has similar situation to the story

animation. In Figure 12, students select one of the simulation from the simulation list (in area ⓐ) and click "Preview Simulation" button (in area ⓑ) which pops up a new window as area ⓒ shows. If students believe the chosen simulation fit the situation in the story, they can click "Next Step" button to go to the next stage.

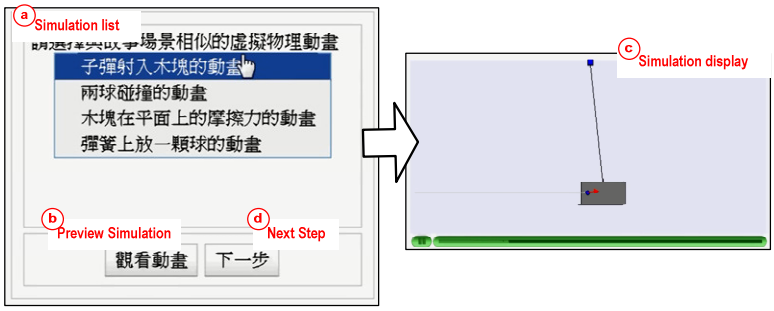


Figure 12. Students can preview a Java simulation (Hwang & Esquembre, 2003) before decide which simulation they would like to use to verify their hypothesis.

Next, students have to connect the objects appear in both of the story animation and the chosen simulation together so they can apply the science concepts they have learnt and start their experiment. In the "cliff escape" example as area ⓐ in Figure 13 shows, students have to find that the rock in the story animation in fact can be seen as the block in "A bullet shooting in a block tying under the pendulum" simulation (in area ⓑ in Figure 13) and the adventurer in the story animation actually is the bullet in that simulation. Students also need to considers which physical quantities they may want to observe or manipulate later and decide which variable belongs to independent variable (which they need to manipulate) and which are dependent variables (which they want to observe).

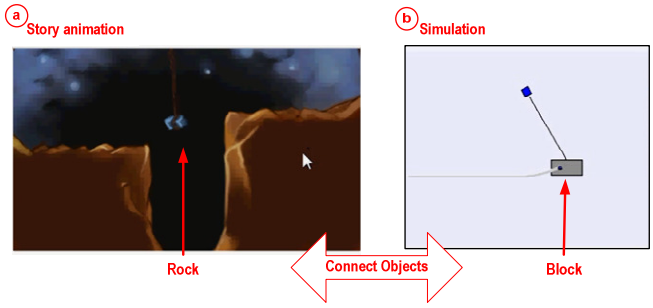


Figure 13. Students can match objects in story animation to the simulation by previewing the chosen Java simulation (Hwang & Esquembre, 2003)

Once students finish the settings for chosen variables, the system shows students again the simulation they chose earlier but this time some control panes are also provided for students doing experiment and watching the results. Area ⓐ in Figure 14 is the control pane, students can play or pause the simulation at any time they want and observe variables' values in area ⓑ. They could also change independent variable's value (e.g., change the bullet's speed from 100 meters per second to 200) in area ⓒ and see the changes of the dependent variable's value through replays. Students need to manually record the data they observed from the simulation from time to time in area ⓓ, and the data will be added to the table in area ⓔ. After data is collected, students can generate a graph by clicking the button in area ⓕ and decide the variables for being x- and y-axes. The generated graph will be shown in area ⓖ.

Students can check the generated graph and consider the relations in-between the two variables; for instance, does the bullet's speed have positive (or negative) correlation with the height that the block will be hit to? In the case that Figure 14 shows, students thought bullet's speed is independent variable and forms x-axis and thought the block's height is dependent variable and forms y-axis. Students can choose what kind of relations the two variables have in area ⓗ.

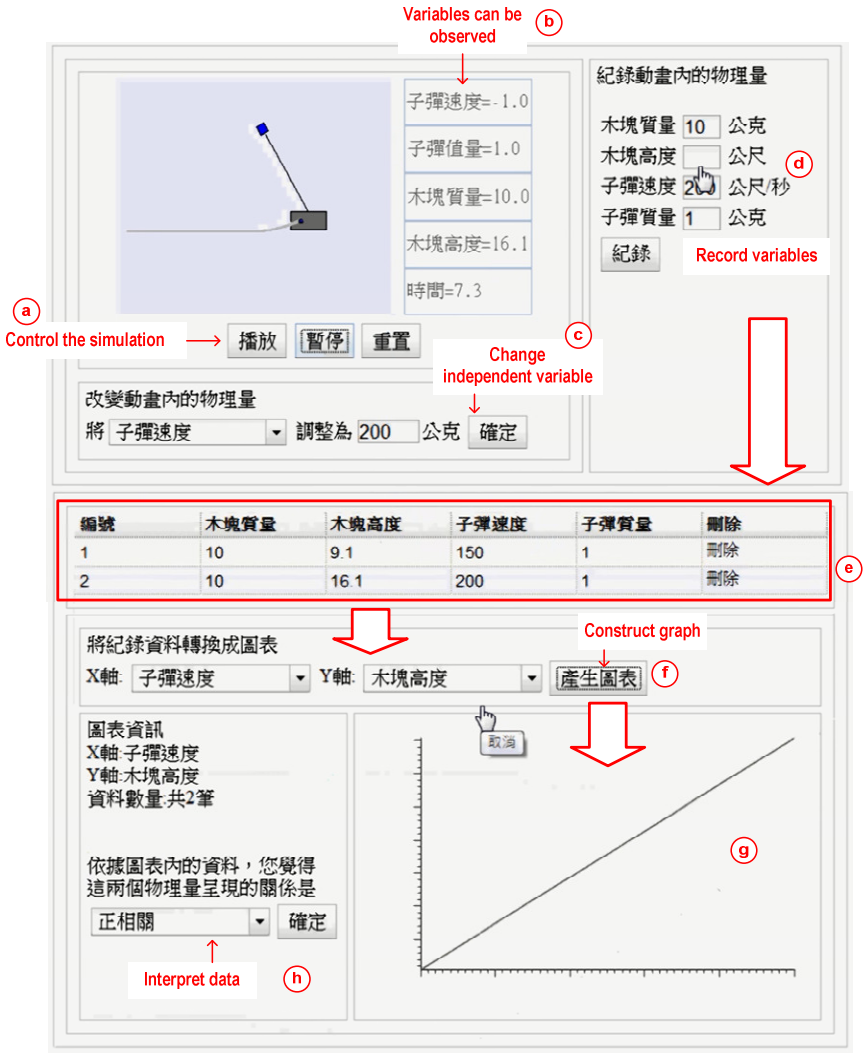


Figure 14. Students can control the independent variable in the chosen simulation as well as observe and record the values of dependent variables. After all data are recorded, students can generate a graph to interpret the relation between independent and dependent variables.

At the end, students need to assess the hypothesis they made earlier according to the experiment results as Figure 15 shows. In this "cliff escape" example, students make a hypothesis – "when the adventurer runs faster and jumps to the rock, he or she may swing higher and reach the higher cliff at the other side of the valley." They further think the situation in the "A bullet shooting in a block tying under the pendulum" simulation is similar to the

story animation and can be used to solve the problem they have encountered in the story. They believe the bullet in the simulation can be seen as the adventurer in the story animation and the block can be seen as the rock. Since the experiment results prove that the bullet's speed and the block's height has positive correlation, increasing adventurer's speed can make the rock gets to higher place when it is swung to the other side of the valley. Their hypothesis is confirmed. If the experiment results can not support the hypothesis they made, they can go back to any previous steps listed in the area ⓑ to re-plan and redo the experiment.

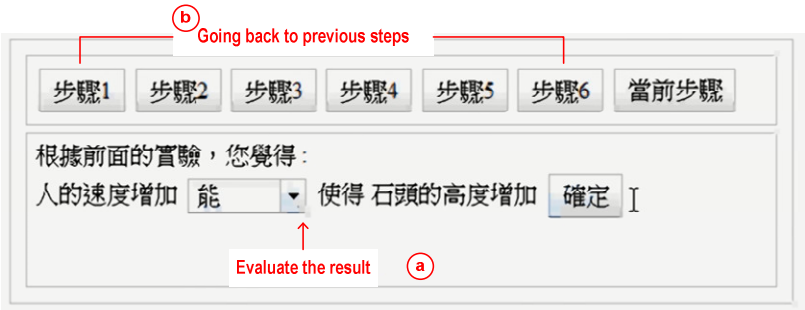


Figure 15. Students can evaluate their hypothesis made at the first stage and see whether or not they need to re-plan or redo the experiment.

5. RESEARCH DESIGN

5.1 Hypotheses and Experiment Design

We have several hypotheses for the proposed story-based virtual experiment environment:

- H1: Story-based virtual experiment environment is useful for students.
- H2: Gender will affect students' acceptance of using the system.
- H3: Students' past Physics grade will affect their acceptance of using the system.
- H4: Students' science process skills will affect their acceptance of using the system.
- H5: Students' past Physics grade is related to their science process skills.

To understand students' acceptance of using the system, this research adopts the Technology Acceptance Model (TAM) from previous research (Davis, 1989) in which twelve 5-point Likert questions for three factors -

Perceived Usefulness, Perceived Ease of Use, and Behavior Intention are designed.

Additionally, this research adopts Test of Integrated Science Process Skills (TIPS) (Monica, 2005) in which 30 items developed to assess students' science process skills. In the TIPS, there are 19 items are related to the four skills which students are going to practice in the proposed system:

- 6 items belong to the skills of stating hypotheses which is corresponding to Stage 1(b).
- 3 items belong to the skills of operational definitions which is corresponding to Stage 1(b).
- 7 items belong to the skills of identifying and controlling variables which is corresponding to Stage 2.
- 3 items belong to the skills of graphing and interpreting data which is corresponding to Stage 4.

Figure 16 shows the relations among factors which are involved in the hypotheses.

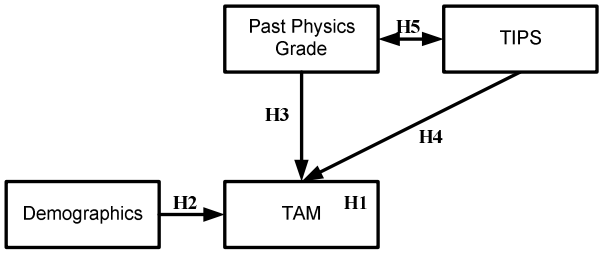


Figure 16. Relations among factors involved in the hypotheses.

An experiment was conducted in a high school class in Tainan City, Taiwan, to verify the hypotheses. There were 31 grade-10 participants (23 males and 8 females) and they all learned basic Dynamics before. In the beginning, participants took 50 minutes to write their TIPS test. After that, the researchers taught them how to use the story-based virtual experiment environment. The system had four story scenes and participants took next 50 minutes to use the system and to solve the problems by conducting their own experiments. At the end, participants were asked to write a questionnaire.

5.2 Reliability and Validity

Before we verified the reliability and validity of the collected data, we found 13 responses were inconsistent in terms of answering the flip-flop items I_6 and I_8. After the removal of the inconsistent responses, we used SPSS 17.0 to test the reliability and validity of the data. Based on the test

results, the TAM questionnaire was eliminated to 10 questions for the three factors. The reliability of the TAM was acceptable as its Cronbach's alpha value is 0.823 (George & Mallery, 2010). Next, we used principle component analysis to test the validity of the TAM. As the results listed in Table 2 show, the data collected is valid.

Table 2. Validity analysis results of the technology acceptance model.

Item	Factor		
	1	2	3
Factor 1: Perceived Usefulness			
I_2: Using Story-based Virtual Experiment Environment would improve my manipulating abilities in Physics experiment.	.928		
I_5: Using Story-based Virtual Experiment Environment would make me understand the problem in the story scenes.	.801		
I_1: I would find Story-based Virtual Experiment Environment is useful to me.	.766		
I_3: Using Story-based Virtual Experiment Environment would teach me how to find the relation between Physics quantities	.748		
Factor 2: Behavior Intension			
I_{19}: I would like to the Story-based Virtual Experiment Environment in the future.		.799	
I_{20}: I would like to introduce Story-based Virtual Experiment Environment to others.		.759	
I_{21}: I would like to use systems similar to the Story-based Virtual Experiment Environment.		.678	
Factor 3: Perceived Ease of Use			
I_6: I would find Story-based Virtual Experiment Environment's user interface easy to use.			.902
I_7: Learning to operate Story-based Virtual Experiment Environment would be easy for me			.693
I_8: I frequently couldn't find the function which I would like to use in Story-based Virtual Experiment Environment.			.658
Eigenvalue	4.322	1.688	1.364
% of variance	43.334	16.883	13.642
Overall α =0.823, total variance explained is 73.748%			

6. EVALUATION AND DISCUSSION

6.1 Findings

Eighteen participants' data, including 14 males' and 4 females' data, were used for the evaluation after the removal of the inconsistent responses. Their

average past Physics grade is 73.28 (male: 74.79; female: 68.00), and the average TIPS score is 70.11 (male: 69.68; female: 71.00). There are no significant difference between male and female participants in terms of their past Physics grade and TIPS score (Past Physics Grade: t = 1.258, p = .226; TIPS Score: t = -.197, p = .847). Table 3 shows the descriptive statistics of the participants.

Table 3. Descriptive statistics in gender, past Physics grade, and TIPS score.

Gender	# of Participants	Past Physics Grade		TIPS Score	
		Mean	SD	Mean	SD
Male	14	74.79	9.553	69.86	9.968
Female	4	68.00	9.345	71.00	11.431
All	18	73.28	9.676	70.11	9.964

The descriptive statistics of the technology acceptance model (TAM) is listed in Table 4. The average score of their technology acceptance level is 3.53 (between Neutral and Agree). The average score for Perceived Usefulness is 3.74, which means, students believe the story-based virtual experiment environment can help them learning Physics concepts. Therefore, hypothesis H1 is supported. However, the average scores for Perceived Ease of Use (PEU) and Behavior Intention (BI) are not high enough and students' perceptions toward the easy of use and the intention of using the proposed system are between Disagree and Neutral.

Table 4. Descriptive statistics of participants' technology acceptance.

Gender	#	PU		PEU		BI		Overall	
		M	SD	M	SD	M	SD	M	SD
Male	14	3.59	0.67	2.76	1.00	2.76	1.00	3.38	057
Female	4	4.25	0.87	3.75	0.32	3.75	0.32	4.08	0.55
All	18	3.74	0.74	2.98	0.98	2.98	0.98	3.53	0.63

PU: Perceived Usefulness; PEU: Perceived Ease of Use; BI: Behavior Intention

There is significant difference between male and female participants' acceptance level (t = -2.169, p = .045 < 0.05) as the data listed in Table 5 shows, which shows female participants accept the use of the proposed system much more than male participants. Therefore, hypothesis H2 is also supported.

Table 5. Independent t-test result for different genders' acceptance levels toward the system.

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig (2-tailed)
PU	Equal variances assumed	1.430	.249	-1.640	16	.120
	Equal variances not assumed			-1.410	4.084	.230
PEU	Equal variances assumed	.726	.407	-1.040	16	.314
	Equal variances not assumed			-1.117	5.414	.311
BI	Equal variances assumed	2.655	.123	-1.912	16	.074
	Equal variances not assumed			-3.176	15.422	.006
Overall	Equal variances assumed	.229	.639	-2.169*	16	**.045**
	Equal variances not assumed			-2.215	5.015	.077

PU: Perceived Usefulness; PEU: Perceived Ease of Use; BI: Behavior Intention

*: $p < 0.05$ (2-tailed)

We also find that there is a significant positive correlation between Perceived Usefulness (PU) and Behavior Intention (BI) factors as the results listed in Table 6 shows. This finding shows that students' intention of using an educational system will be increased if they think the system is useful.

Table 6. Correlation analysis among TAM factors

	PU vs PEU	PU vs BI	PEU vs BI
Pearson Correlation	.201	**.557***	.273
Sig. (2-tailed)	.425	.016	.273
N	18	18	18

PU: Perceived Usefulness; PEU: Perceived Ease of Use; BI: Behavior Intention

*: correlation is significant at the 0.05 level (2-tailed).

We also want to know whether or not students' past Physics grades and TIPS scores will affect their acceptance of using the proposed system. The Pearson Correlation test shows that there is no significant correlation between students' past Physics grade and TAM factors as well as between students' TIPS scores and TAM factors. Furthermore, we conduct another round of correlation analysis for the TIPS 19 items whose associated skills can be practiced in the proposed system against to the three TAM factors. The results still show no significant correlation between the four skills and TAM factors. Table 7 lists all the analysis results of the Pearson Correlation test. We also find that there is no significant relation between students' past Physics grades and TIPS scores ($r = .289$, $p = .244 > 0.5$). Therefore, the last three hypotheses are not supported.

Table 7. Correlation analysis between students' tests scores (including past Physics grade and TIPS score) and TAM factors.

		PU	PEU	BI	TAM
Past Physics Grade	Pearson Correlation	-.124	-.404	-.012	-.214
	Sig. (2-tailed)	.624	.097	.963	.395
	N	18	18	18	18
TIPS Score	Pearson Correlation	.448	-.076	-.106	.135
	Sig. (2-tailed)	.062	.763	.675	.592
	N	18	18	18	18
TIPS_Var Score	Pearson Correlation	.444	.089	.135	.308
	Sig. (2-tailed)	.065	.729	.592	.213
	N	18	18	18	18
TIPS_Hyp Score	Pearson Correlation	.280	-.173	-.373	-.106
	Sig. (2-tailed)	.280	.492	.127	.676
	N	18	18	18	18
TIPS_Def Score	Pearson Correlation	.359	-.192	.270	.227
	Sig. (2-tailed)	.144	.445	.278	.364
	N	18	18	18	18
TIPS_Grp Score	Pearson Correlation	-.112	.020	-.408	-.238
	Sig. (2-tailed)	.657	.937	.093	.341
	N	18	18	18	18

PU: Perceived Usefulness; PEU: Perceived Ease of Use; BI: Behavior Intention; TAM: Technology Acceptance Model; TIPS_Var Score: Identifying and controlling variables score; TIPS_Hyp Score: Stating hypotheses score; TIPS_Def Score: Operational definitions score; TIPS_Grp Score: Graphing and interpreting data score

6.2 Discussion

Although the average students' acceptance levels toward the proposed system are between Neutral and Agree, their perceived ease of use and intention of using the system are only between Neutral and Disagree. We interviewed some students and wanted to know why they don't think the system is ease of use. One of the reason is they can not find the functions they want to use at very beginning; hence, giving students enough time to get themselves familiar with the system before starting the pilot relevant activities should be considered for future pilots. Another reason is the students feel the simulations (i.e., the EJS as Figure 14 shows) is too complicated to use than other steps, and students need more time to learn how to use the user interface of the EJS. Therefore, to make students have higher acceptance level towards the use of the system, simplifying the user interface of the simulation would be important.

On the other hand, female participants have higher acceptance in terms of using the system according to the t-test results listed in Table 5. This finding is similar to other studies on gender differences in learning technology research domain (Arbaugh, 2000; Viberg & Gronlund, 2013). Female

participants may be more active in learning process than male participants (Gonzalez-Gomez, Guardiola, Rodriguez, & Alonso, 2012) and may prefer storytelling games (Robertson, 2012). Robertson's research result indicates that story-based educational game may engage female students' better and our research result is in line of it.

Female participants may also have higher intention of using the system because of the perceived social pressure, such as the pressure from teachers (Cheung & Lee, 2011). To verify this hypothesis, we further evaluate the responses of two social inference questions:

- I_{13}: I use the system because my teacher wants me to play it.
- I_{14}: I use the system because my teacher asks me to play it

Although we find that there is no significant gender difference in the responses of the two questions (I_{13}: $t = -1.072$, $p = .300 > 0.05$; I_{14}: $t = -.905$, $p = .379 > 0.05$), the correlation analysis results show that both questions significantly positive correlation to TAM (I_{13}: $r = .726$, $p = .001 < 0.05$; I_{14}: $r = .509$, $p = .031 < 0.05$). Teachers' attitudes toward the use of new technology for students learning are significantly influence students' acceptance levels toward the new technology. Researchers should clearly explain to teachers the benefit that both teachers and students can receive through the use of their proposed educational systems (including educational games) and get teachers' support before apply their proposed systems and games into student learning process.

Our research result also shows that there is no significant correlation between students' grades (include past Physics grades and TIPS scores) and their technology acceptance levels. The finding indicates that the system can attract all students include both lower and higher academic achievement students. With teachers' encouragement, lower academic students may spend more time on using the system and practice their science process skills. When they find that their skills are improved, they may have more intention to actively use the system because the analysis result shows that Perceived Usefulness has significantly positive correlation to Behavior Intention factor.

Although we find that there is no significant relation between students' past grades and TIPS scores, the reason may be – the traditional Physics lessons are not focusing on science process skills. Therefore, using story-based virtual experiment environment could fill in the missing puzzle piece that traditional science learning has and enhance students' science process skills.

7. CONCLUSION

This research designs a story-based virtual experiment environment for students practicing their science process skills. Students can improve their skills at every stages of model for problem solving activities. These practices could help students solve the real world problems through applying the knowledge they learned in the school.

The experiment result shows that students, especially for female students, believe that the system is useful for them in terms of learning. Since students' past physics grades and TIPS scores won't influence their intention of using the system, we could design more attractive stories to engage both low and high academic students practicing their science process skills, which is usually not paid attention in traditional science learning.

After the removal of the inconsistent responses, this research only analyzes 18 students' intentions of using the proposed system. Collecting more data for the analysis should be considered in the future studies. Students' behaviors in the system should also be analyzed according to the science process skills at each stage.

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