

# Using Story-based Virtual Experiment to Help Students Building Their Science Process Skills

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**Abstract:** Science Process Skills are what students use to solve scientific problems. This research designs a virtual experiment environment (V.E.E.) to help students building their science process skills by doing virtual experiments. To motivate students practicing their science process skills, this research designs virtual experiment which integrates story elements into the virtual experiment environment and asks students solving the problem described in the story. Students solve the problem by following the Seven Problem Solving Stages. Each stage helps students practicing different science process skills, e.g. observing, formulating hypothesis, and classifying. To reduce teachers working loads, teachers only need to focus on designing the story backgrounds and establishing the connections between story elements and Physics experiment elements. The virtual experiment environment can automatically generate the virtual experiments in which the seven problem solving stages are embedded. A practical system with a complete example is demonstrated at the end of this paper.

**Keywords :** Science Process Skill, Virtual Experiment Environment, Knowledge Structure, Problem Solving.

## 1. Introduction

Many researchers use Easy Java Simulator (EJS, Esquembre & Zamarro, 2001) to build virtual labs in which students can see real-world phenomena and learn relevant knowledge (Hwang & Esquembre, 2003; Jara, Candelas, Torres, Dormido, Esquembre, & Reinoso, 2009). By manipulating experiment kits in virtual labs, students can practice various science process skills, e.g. observing, measuring, and inferring (Funk, Fiel, Okey, Jaus, & Sprague, 1985). To motivate students practicing their science process skills in the virtual labs, this research applies story elements to create a virtual experiment environment for students solving problems with fun. Teachers only need to design the story elements at the beginning, and the virtual experiment environment will generate a series of problem solving steps to lead students solving the problem by using their science process skills.

In Section 2, this paper introduces three bases of this research, including science process skills, context-aware knowledge structure, and virtual experiment environment. The revised seven problem solving stages and the details of the story-based knowledge structure are revealed in Section 3. Section 4 designs the components used for constructing problem solving stages in the virtual experiment environment with a complete example of the system. Section 5 gives readers a brief summary and possible future works.

## 2. Science Process Skills and Knowledge Structure

This research's goal is to development a system which can generate story-based virtual experiments to motivate students practicing their science process skills. Virtual Experiment Environment (V.E.E.) and context-aware knowledge structure are two important relevant researches.

### Virtual Experiment Environment with Science Process Skills

Science process skills are defined as activities which students have to solve the scientific problems (Rambuda & Fraser, 2004). Some researchers develop instruments to help students practicing their science process skills in intensive robotics course (Sullivan, 2008); and others use instruments to measure students' science process skill levels (Temiz, Tasar, & Tan, 2006). Virtual lab is one of the virtual experiment environment in which students can practice their science process skills via computer simulations (Yan, Liang, Du, Saliyah-Hassane, & Ghorbani, 2006; Martin, Urquia, & Dormid, 2009).

Kuo et al. (2000) designs the Virtual Experiment Environment (V.E.E.) which supports an environment for students practicing their science process skills. V.E.E. also applies seven problem solving stages (Assessment of Performance Unit, 1986) to navigate students solve the scientific question. Furthermore, they also build the connections between seven problem solving stages and science process skills as Figure 1 shows. At each stage, the students may be asked to use various science process skills to achieve the goal of the stage. Different science process skills covered by different stages are on the right hand side of Figure 1.

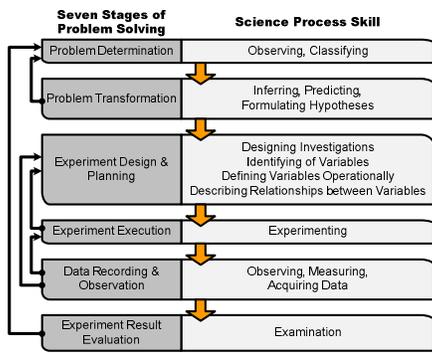


Figure 1. The connections between science process skills and seven stages of problem solving

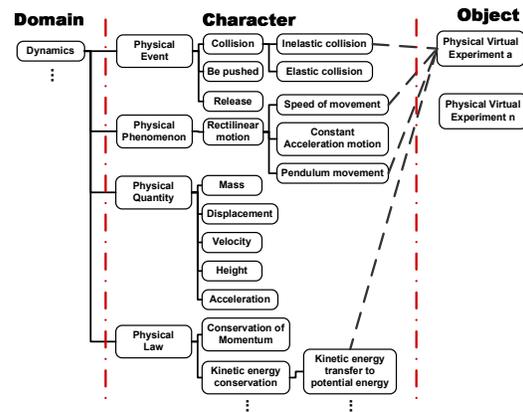


Figure 2. Context-aware knowledge structure example

### Context-Aware Knowledge Structure

Many researchers discuss constructing the knowledge structure which represents students' mental models. Concept Map (Novak, 1984) is widely used by psychologist and educators, and Knowledge Map (Kuo, Change, Dong, & Heh, 2002) is used for solving the Physics problem automatically. To automatically generate the virtual experiment, this research chooses Context-Aware Knowledge Structure (Wu, Chang, Chang, Liu, & Heh, 2008) to store the concepts and objects in the virtual experiment. The Context-Aware Knowledge Structure has three layers as Figure 2 shows. Domain layer denotes the subjects and topics of the learning environment. Character layer stores the domain concepts. Object layer represents the real learning objects. Take Figure 2 as an example, *Physical Virtual Experiment a* is a virtual experiment for students learning Dynamics in Physics. The objects in *a* will have *Inelastic collision* and the objects' movement speeds will be changed. *Inelastic collision* and *Speed of movement* are two *Dynamics* domain concepts.

## 3. Story-based Virtual Experiment

The revised seven problem solving stages integrate story elements into the process of students doing virtual experiment. Following Kuo et al. (2000)'s research, each stage is redefined as:

1. Problem Determination: the students need to describe the relevant Physics problem after they read the story and

make assumptions to solve the identified problem.

2. **Problem Transformation:** the students choose a virtual experiment to prove the assumptions they have made at first stage. They can make their choice by observing the similarity between the story and the virtual experiment. The number of objects, the Physics events, and the Physics Phenomenon are the features for students determining the similarity. The students should also map the attributes described in the story to relevant Physics concepts, including Physics laws, Physics quantities, and the Physics objects.
3. **Experiment Design & Planning:** the students need to decide the manipulating and responding variables for the chosen experiment.
4. **Experiment Execution:** the students play or stop the simulation in the virtual experiment. They can also control the manipulating variables in order to observe the variation of the responding variables.
5. **Data Recording & Observation:** when students do the experiment, they can observe how the values of the responding variables change and record the values of both manipulating and responding variables from time to time.
6. **Data & Information Explanation:** The values of manipulating and responding variables can be drawn on the two-dimension figure. The students need to check the figure and to determine the relation between the manipulating and the responding variables is direct, inverse, or exponential.
7. **Experiment Result Evaluation:** According to the experiment results, the students can evaluate if the assumptions they made at the beginning is correct.

Figure 3 shows the process of the revised problem solving seven stages and its relations to the science process skills. We consult science education teachers and researchers to find out which science process skills that the students need to have at different stages. For examples, students need to use the formulation hypotheses skill at the problem determination stage and the students need to classify and identify variables at the problem transformation stage, furthermore, they also need to observe everything at all the time as they are in the real lab.

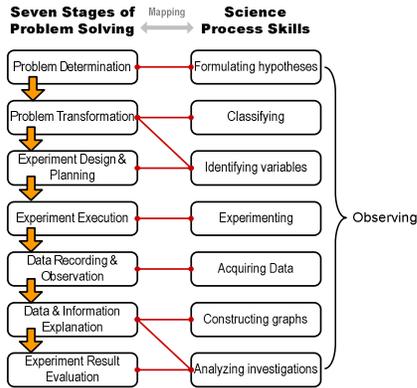


Figure 3. Revised Seven problem solving stages

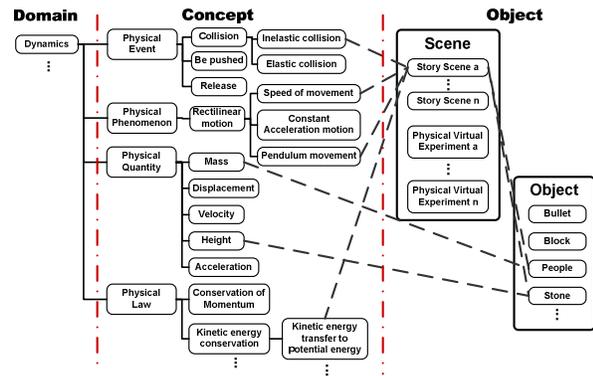


Figure 4. Story based physics knowledge structure

This research also designs multiple-choice questions to interact with students. Four major types of information are needed to be stored in the knowledge structure, which is based on the Context-aware knowledge structure mentioned in the previous section, in order to generate the multiple-choice questions automatically. Domain and Concept are the information related to the domain knowledge; Scene and Object are the information related to the story scene and experiment:

1. **Domain:** The domain layer has the same definition as the Context-aware knowledge structure which presents the subjects and topics of V.E.E., such as *Dynamics* and *Kinematics*.
2. **Concept:** The concept layer is renamed from the characteristic layer in the original Context-Aware Knowledge Structure. Four root concepts are used for physics' story-based knowledge structure, which are physical event, physical phenomenon, physical quantity and physical law. For example in Figure 4, rectilinear motion is the phenomenon of science; mass is the quantity of the science; kinetic energy conservation is the law of the science.
3. **Scene:** The object layer in the original Context-Aware Knowledge Structure is separated into scene and object layers. In order to integrate the story in the V.E.E., the scene layer stores the information about the story information, such as the animation and text describing the story. Furthermore, the story layer also stores the information of the simulator scene, such as the experiment simulator file path, the variables manipulated in the

virtual lab etc.

- Object:** The objects or characters in the story and experiment scenes are stored in the object layer. For example, “People” and “Stone” are two characters/objects in the scene “Story Scene a” as Figure 4 shows.

Another enhancement of story-based knowledge structure from the original context-aware knowledge structure is schema. Figure 5 shows examples of schemas belonging to Physical Law and Physical Quantity. The Conservation of Momentum concept, which is a concept of Physical Law, stores the physical law (ex. rule  $m_1v_1 + m_2v_2 = m_1v_3 + m_2v_4$ ), physical quantity (ex. mass and velocity) and the relation between the variable (ex.  $m_1$  and  $v_3$  has proportional relation) in the schema. To identify the symbol in physical law, the concept mass’s schema, which is a child node of Physical Quantity, stores the symbol of the mass used in the physical law, such as  $m$ ,  $m_1$ , and  $m_2$ .

Conservation of Momentum		
Quantity	Mass	
Quantity	Velocity	
VariableRelation	$m_1$ $v_3$	Proportional
VariableRelation	$m_2$ $v_3$	Inverse
VariableRelation	$m_1$ $v_4$	Proportional
VariableRelation	$m_2$ $v_4$	Inverse
Rule	$m_1v_1 + m_2v_2 = m_1v_3 + m_2v_4$	

Mass	
LawVariable	$m$
LawVariable	$m_1$
LawVariable	$m_2$

Figure 5. The examples of the Concept Schema

#### 4. Virtual Experiment Environment and System Demonstration

The story-based knowledge structure designed in section 3 is used to generate the virtual experiment in V.E.E.. Figure 6 shows the process for the teacher creating the story scene of the virtual experiment. In the beginning, the teacher creates a story scene and fills up the data in the story scene with its related objects as the first and the second steps in Figure 6. After creating the story information, the teacher should choose what Physical events and what Physical phenomena the story described (step 3 and step 4 in Figure 6). These two steps help V.E.E. system finding suitable simulators from the Story-based Knowledge Structure for students to execute in the process of problem solving. At step 5, the teacher should setup the Physical quantity that students should observe in the virtual lab. The Physical laws the teacher wants students to learn are set up in step 6. After the process in Figure 6, the V.E.E. system constructs the problem solving components for each stage.

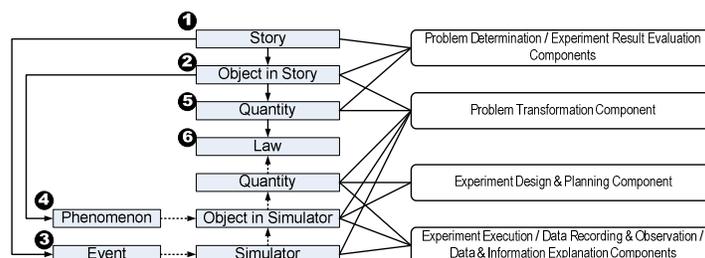


Figure 6. Flow of the setting virtual experiment content with corresponding components

After the process in Figure 6, the V.E.E. system constructs a virtual experiment with seven problem solving stages. Each stage of the problem solving is generated by the corresponding component. Problem Determination and Experiment Result Evaluation Components use the data in the Story, Object in Story and Quantity schemas. The problem Transformation Component asks students comparing the data between Story and Simulator, which needs the information in Object in Story, Object in Simulator and the Quantities in both scenes. The Experiment Design & Planning Component only focuses on the Object in Simulator and the Quantity in Simulator. The last three components asks students to execute the virtual lab stored in the Simulator schema and observe the Object in Simulator and its Quantity.

The example demonstrated in this section is asking students helping the adventurer in the story by using the Physical concepts they’ve learned. The adventurer is standing by the cliff and planning to go through the other side of the cliff which is higher then the side where the adventurer is. When the student start solving the problem, they can read the story description with animation and the problem they should solve in the beginning. The possible assumptions for solving the problem are also generated by the system in this page as Figure 7 shows. After selecting the

assumption, students go to the next page generated by the problem transformation component. The problem transformation component displays several videos of the simulator. Students can observe the videos of the simulator and decide what simulator can help them solve the problem. Figure 8 shows the page for students selecting the simulator they want to use later. Students can click “Observe this animation” button to watch what Physical phenomena the simulator will execute. If students believe the simulator is the one which can solve the problem, they could click “Select this animation” button.

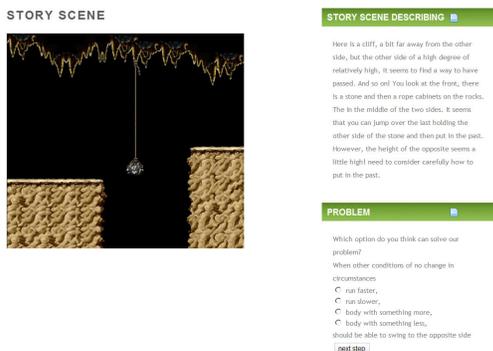


Figure 7. Problem Determination stage snapshot

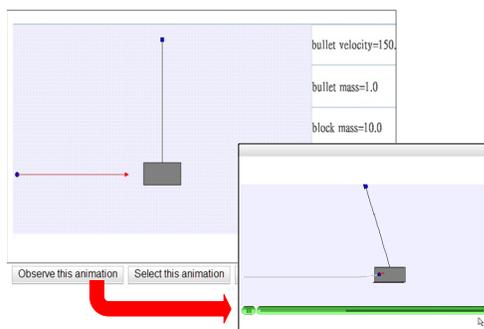


Figure 8. Simulator selection page

After student select the simulator for solving the problem, the problem transformation component construct a mapping question which ask students to find the corresponding between the object in the story scene and the object in the simulator scene. The next stage is constructed by the experiment design and planning component which is demonstrated in Figure 9. Students select Physical quantity as the manipulating variable or responding variable. After students deciding the manipulating and responding variables, students can execute the simulator in the next stage generated by the experiment execution component. Figure 10 shows the snapshot of the experiment execution stage with simulator. Six functions are listed in the page. Students can click “Set parameters” to change the value of manipulating variable in this simulator and click “operation animation” to play or pause the animation in the simulator. When students click the other four buttons, the Data recording and observation component generates the lab notebook and records the experiment data. The Data and information explanation component also generate question asking the relationship about manipulating and corresponding variables in the lab notebook.

At the last stage, the Experiment result evaluation component displays the story scene again and asks students if their assumption in the first stage is correct. If students think the assumption is correct, they can click the option “can” and end up the entire problem solving stages; otherwise, if students think the assumption is incorrect, they can click the option “can’t”, and the system will back to the first stage for students processing the problem solving stages again.

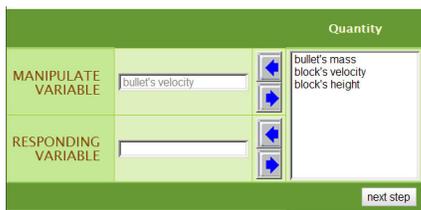


Figure 9. Decide the manipulating variable and responding variable in the experiment design and planning stage

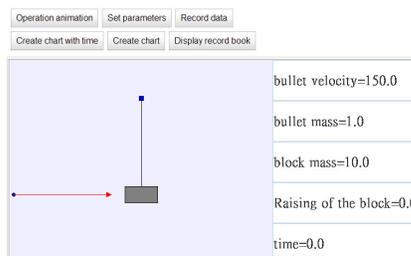


Figure 10. Operation the virtual lab in the experiment execution stage

## 5. Conclusion

This research designs the story-based knowledge structure for automatically generate virtual experiments in the V.E.E., which help students practicing their Science Process Skills. The teacher only needs to input the information about the story and the correspondence between story and simulator, the V.E.E. will generate a series of steps for

students solve the problem by following the Seven problem solving stages. A practical example is demonstrated in the end of the paper.

Though the V.E.E. system has already recorded students' operating log, how to analyze students' log and diagnose students' Science Process Skills can be a good challenge of this research. Furthermore, using more interactive interface, such as intelligent agent, to navigate students in the story-based learning environment can also be another future study for this research.

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