Chapter 10
Exploring the Relationship Between Learners' Uncertainty Level and Learning Performance in an Authentic Problem-Based Learning Environment

Kah Heng Loh
School of Liberal Arts and Sciences, Taylor's University, Malaysia

You Ping Lim
https://orcid.org/0000-0003-0046-1264
School of Liberal Arts and Sciences, Taylor's University, Malaysia

ABSTRACT

Many educators believe that learners' learning experience can be enhanced by infusing uncertainty into their learning process. The authentic problem-based learning (APBL) model allows uncertainty to be incorporated into ill-structured problem to motivate learners' learning process. This study looks into the relationship between learners' uncertainty level and learning performance in APBL model which involve participation of 78 engineering students from Taylor's American Degree Program. A questionnaire consists of 30 items of uncertainty construct and 10 items of learning satisfaction is developed to measure learners' uncertainty level and satisfaction at the end of APBL. Learners' learning satisfaction, learning attitude, and learning score on APBL activities which form the learning performance is computed. The Cronbach's alphas for uncertainty construct and learning satisfaction are 0.89 and 0.92 respectively. The zero order Pearson's correlation analysis showed a strong negative correlation between uncertainty level and learning performance.

DOI: 10.4018/978-1-7998-6445-5.ch010

INTRODUCTION

The term "uncertainty" has been used in various discipline with different interpretation. In term of teaching and learning aspect, uncertainty is always associated with anxiety, ambiguity and confusion, particularly in the traditional teaching approach where "certainty" is the gold standard of teaching and learning outcome. Thus, educators and students avoid uncertainty as much as they can. The current shift of teaching paradigm to learning paradigm with the student-centered learning approach such as Problem-based learning (PBL) has been increasingly gaining its popularity in the higher learning institutions. The unique feature of PBL is crafting the ill-structured problem/ PBL scenario. The unique feature of PBL is the injection of uncertainty naturally as a source of intrinsic motivation and a stimulus to learning which appears as the natural provocations for real learning. The uncertainty in PBL is originated from the lack of knowledge due to the fact that they are not exposed to curriculum input prior to the PBL question given to them. Students are required to assess what they know and what they do not know, and they are challenged to make decision to fill the gap of knowledge uncertainty in order to construct the new knowledge. This feature in the learning paradigm is very much different from the traditional approach of teaching paradigm where students and lecturers believe that the purpose of teaching and learning is the resolving of uncertainty level and the main resources to close the gap of knowledge and reduce uncertainty are teachers and textbooks.

Today's university students who have completed secondary education are highly dependent on teachers who spoon fed them with knowledge to reduce uncertainty in learning. Cynthia (2015) reported that today's learners face a difficult, uncertain and complex future. As such, universities must work to equip learners with the skills they need to confront with new challenges, which can be achieved by presenting ill-structured real-world problems to students before they are taught with the topic or knowledge in PBL approach (Savery, 1995).

LITERATURE REVIEW

Problem-Based Learning (PBL)

Education has long been focused on teacher centered and instructional approach which emphasized on teaching students to provide a correct or definite answer. Student often completes assignments, do well on tests and get good grades; yet, lack critical thinking component (Brooks & Brooks, 1993). Brooks and Brooks (1993) articulated that lecturers too often ask students to recite, define, describe, or list facts. This approach has often allowed students to be passive in the classroom. Students, not knowing how to be active participants in the lecture, have relied on transcription, memorization, and repetition to reduce uncertainty in learning. They perceived this mode of teaching and learning is the best way to reduce uncertainty, as they believe that knowledge consists of right answers and learning is the memorization and reproduction of these answers (Perry, 1970). To them, information seeking is seeking "correct answers" and fact from lecturers and textbooks only. The current educational reform reflects the importance of learning not only to acquire content information, but also emphasizing in generic skills such as critical thinking and digital literacy skills. The phenomenon of "information overload" due to exponential increase in the number of information resources and technology tools available today has put digital literacy skill and critical thinking skills as predominant skills on the part of today's university students. Students actively search for information and construct knowledge by building on knowledge they have gained previously (Cross, 1998). They are benefited from working together, and they may learn best from teaching each other (McKeachie, et al., 1986). Research also suggests that students learn best in the context of a compelling problem (Ewell, 1997); and they also learn through experience (Cross, 1998). This new understanding has given rise to the notion of a paradigm shift in higher education, from teaching focused to learning focused on teaching and learning (Barr and Tagg, 1995). PBL possesses these features as it applies the facilitation process to help groups of motivated learners to identify and understand their own learning needs and to assists them to fulfill these needs in the facilitator-learner partnership approach.

PBL is an educational approach in which ill-structured problems serve as a stimulus to trigger learning. Students study in PBL classes work in teams to solve complex and compelling "real world" problems. They need to develop skills in identifying, collecting, evaluating, and synthesizing information as they first define and then propose a solution to a multi-faceted problem. The instructor who conducts PBL class facilitates the learning process by monitoring the progress of the learners and asking relevant questions to move students forward in the problem-solving process and guides students as they search out appropriate resources. Terry (2017) articulates that the key and defining characteristic of problem-based learning is having the problem at the *start* of the learning process for students to experience before they receive prior content knowledge. This *motivates* them to add on new knowledge through independent study, constructing knowledge together in PBL activities and learning from other existing knowledge. Terry (2017) pointed out that the four key characteristics of PBL are: problem; PBL tutorial; PBL process and learning. However, Brooks and Brooks (1993) articulated that relevance is a primary issue in PBL, which they deem it one of the universal principles of constructivist teaching. They suggest searching for windows into students' thinking in order to craft problems of increasing relevance in PBL.

Development of PBL

PBL approach was first developed in the 1960s at McMaster Medical School by faculty due to perceived need to produce graduates who were prepared to deal with information explosion, to think critically and solve complex problems. Following the successful implementation of PBL at McMaster Medical School, many medical schools around the world began to adopt the McMaster model. In medical schools, PBL is an approach to structure the curriculum that involves confronting students with problems from practice which provide a stimulus for learning (Boud & Feletti, 1991). However, there are many possible forms that a curriculum and process for teaching and learning might take and still be compatible with this definition (Boud & Feletti, 1991). Educational and professional schools also began to feel many of the same needs as medical schools, so they began to adopt the approach as well, although in different forms, such as hybrid PBL and traditional curricula and course-by-course models. These PBL models also spread to institutions around the world.

Educators and employers alike began to call for change in undergraduate institutions in the past decades (Jones, 1997). They also wanted students who could think critically, solve problems, and work in teams. The Boyer Commission Report articulates that these changes led to recommendation of inquiry-based learning as a vehicle for improvement (The Boyer Commission, 1998). Since then, many undergraduate institutions began to develop PBL programs and curricula. Among these institutions of Higher learning, Aalborg University in Denmark has one of the most comprehensive undergraduate PBL curriculums. The University of Delaware has turned attention toward PBL.

PBL in Engineering Education

In the field of engineering education, there arose an increasing pressure to call for change in its curriculum. The traditional lecture-tutorial plus practical (laboratory) classes is viewed as content driven with staff enforcing rigid course outline. These engineering courses ensure technical competent graduates who have successfully met the responsibilities of the profession to provide goods and services to society. However, the rapid growth of the professional knowledge has resulted inability of student to master all of the discipline knowledge in the span of undergraduate study. Moreover, students are also increasingly being criticized for their lack of complementary skills (Mohd Ariffin et al., 2004). Thus, universities around the world are preparing for the paradigm shift by restructuring their courses using PBL as a vehicle for such changes. Mohd Ariffin et al. (2004) reported that PBL has been adopted in engineering courses worldwide. Among those universities, in United Kingdom, University of College London (UCL) and University of Manchester Institute of Science and Technology (UMIST) have implemented PBL in Chemical Engineering course as well as Electrical and Electronic Engineering courses since 1998, and PBL was introduced as the primary teaching method for undergraduate engineering programs at the University of Manchester in September 2001. In Australia, the universities that have introduced PBL in their engineering degrees are Monash University (civil engineering degree); Curtin University (Mechatronic Engineering); and University of Southern Queensland (Engineering and Surveying). In United State, the department of Chemical Engineering of McMaster University has implemented PBL in the early 1980's, while the Aeronautics and Astronautics Department at Massachusetts Institute of Technology (MIT) implemented a PBL curriculum in 1997. Besides, other universities in the U.S. which implemented PBL include University of California Irvine (School of Engineering) and University of Minnesota (Civil Engineering). Other universities across the world do have courses in their engineering programs that are conducted with PBL approach. Aalborg University in Denmark implemented a PBL curriculum in 1974 (Kjersdam, 1994). Temasek Polytechnic and the Republic Polytechnic in Singapore have completely PBL curricula for computer, electrical and industrial systems engineering diploma programs (Mohd Arrifin et al., 2004). Borhan (2012) reviewed that there has been no comprehensive PBL review that specifically focus on Malaysian higher education by far.

In Malaysia, the faculty of Chemical and Natural Resources Engineering of University Technologi Malaysia has introduced PBL in the Process Dynamics and Control subjects in 2003 (Mohd Arrifin et al., 2004). It was reported that the students had better understanding of the subject with PBL compared to the traditional lecture delivery approach. In University Malaya, PBL was made known on the campus of University Malaya in 2001, although elements of PBL had already been introduced in the medical courses at the Medical faculty much earlier in their New Integrated Curriculum (Azila et.al., 1999). According to Salimah (2003), University Malaya has embarked on a pedagogical reform in the instruction of undergraduate programs using the PBL method through the top-down approach embedded in the policy statements by the University's top management. All the university's teaching staff have been required to rethink their teaching methods, to include positively utilize strategies, and overtly recognize the students' cognitive abilities and skills. The University Senate subsequently agreed that PBL should be used in teaching some undergraduate courses including engineering degree. Following the development of Taylor's Graduate Capabilities (TGC) initiatives (Ang and Lim, 2007) at Taylor's University, it provides evidence that the management of Taylor's University has a strong determination to encourage its academic staff to incorporate PBL element into their respective course of teaching. This move has enabled Taylor's University to develop and produce graduates with a wide range of generic skills as well as content knowledge, so that they will become life-long learner, and obtain high recognition in their future employability. Thus, academic staff in Taylor's University have adopted PBL in various modules, including Physics course since 2007.

Uncertainty

It has been known that human's daily activities are involved with uncertainty (Weber, 1997). These uncertainties will shape our action in seeking additional information to resolve unknown situation. Because of uncertainty, people seek information to make decisions and solve problem. It can be seen that uncertainty occurs in all aspects of our life. Generally, anxiety, concerns, emotions that we might encounter are due to the uncertainty. Uncertainty construct has been studied in various area, such as artificial intelligent in computer science and engineering (Horvitz, et. al., 1995); medical science (Shortliffe, et. al., 1997); decision making (Barnard, 1938; Simon, 1947); psychology (Jamis and Mann, 1977; Einhorn and Hograth 1986) and economics (Vickers, 1994; Hamouda and Rowley, 1996).

Uncertainty may be viewed differently from different angle, such as (1) "a lack of knowledge of the situation" (Barnard, 1938; Simon, 1947; Allison, 1971; and Nutt, 1990); (2) a bias that interferes with rational decision making and needs to be controlled (Aiginger, 1987; Baird, 1989; Nutt, 1990; and Hey, 1993); and, (3) a psychological perception that creates fear or indecision that is best reduced through heuristic techniques or procedures (Agor, 1986; Simon, 1987; McCalla, 1992; Nigel, 1993; Covey et al., 1994). All this view has expressed uncertainty as an attribute of how one knows what was known in the aspect of epistemology. This has also led to the development of four branches of uncertainty literature based on an actor's (individual, group, or organisation) (1) ability to gather and process information; (2) ability to predict consequences of actions; (3) use of intuition; and (4) perception of the environment (Weber, 1997: 455*)*.

Weber (1997) articulated that uncertainty consists of four constructs, namely temporal uncertainty, physiological uncertainty, psychological uncertainty, and sociological uncertainty. Temporary uncertainty is the influence of time on knowledge, which can be divided into known, unknown and unknowable. Known knowledge is all the data and information that humankind have recorded and retrievable. However, this known information may become unknown as one goes into the past and more information has been lost. Unknown is all data or information that exists, but has not been recorded or was recorded, and has been lost over time. This may become known if enough information has been analyzed and understood after some time. This known and unknown exists in the present and the past. The unknowable exists in the future, which will never be known because it does not exist. This unknowable can be guessed, but is never certain. In a logical manner, one may search the past and the present to accumulate, filter and integrate data and information to predict the future event or the unknowable that exists as a function of time.

The physiological uncertainty is the physical limitations on searching mechanisms and how they interact with the gathering information and passing the information to the brain. This type of uncertainty focuses specifically on the five senses, the ability of the individual to use them, and the influence it has on the actor's ability to know and act. Thus, the physiological uncertainty is affected by the reliability of the biological capability of search, filtering, compiling and integrating mechanisms. Uncertainty may be increased due to biological impairment of the searcher.

The psychological uncertainty is the limitation of human brain in the interpretation of gathered data or information. It comprises of the way one perceives and reasons base on his intelligence and mental attributes, which poses limitations to the acquisition of knowledge (Barnard, 1938 and Simon, 1947, 1976). The perception and reasoning ability of the searcher influences his searching of information and the way it is processed. Perception of fear or distrust may cause the searcher to discount certain data that is gathered and in turn provide a perception of uncertainty (McCalla, 1992). Likewise, feeling of confidence can cause an actor to only accept data which reinforces current knowledge and thus produce perceptions of absolute certainty (McCalla, 1992).

The sociological uncertainty is caused by the limitation on searching, filtering, compiling and integrating mechanisms which is influenced by the social units due to deliberate interaction (Laws, regulations, rules and procedures) or non-deliberate interaction (norms, culture beliefs and customs). This social interaction will affect how data is recorded for future use, what information will be preserved and save and what information will be discarded, thus, affecting what is possible to know and what will become unknown.

Uncertainty in Education

Uncertainty in teaching and learning is slowly gaining attention by educators in their teaching and learning in the recent years. According to Lee (1998), students and lecturers in the traditional lecture system believe that the purpose of teaching and learning is the reduction of uncertainty. This is the common practice in schools, colleges and universities in Malaysia for decades. They believe that knowledge consists of right answers and learning is the memorization and reproduction of these answers. Ben Johnson (2011) articulated that "Teachers need to inject a little uncertainty into their lessons every day because it engages students at the "analysis and above" levels. It forces the students to evaluate what they know and what they do not know and make a decision about what to do about it". He further describe that "one of the main goals of the educational approach known as constructivism is to prepare learners for uncertainty by helping them feel comfortable in postulating, guessing, hypothesizing, conjecturing, and testing their theories". However, Ronald A. Beghetto (2017) explains that in the traditional classroom, teachers replaced uncertainty with over-planned learning experience by providing a well-defined problem, teaching students how to solve the problem and leading to desired outcome. This is because teachers themselves are uncomfortable with uncertainty, they tried to avoid uncertainty, and attempt to resolve it quickly when they experience uncertainty. Ronald A. Beghetto (2017) proposed a shift in the conception of uncertainty by inviting uncertainty into classroom to foster the problem solving skills in students. He explained that uncertainty can be categorized into bad and good format. Bad uncertainty will lead to chaos in learning experience because it lacks proper support and structure. However, good uncertainty can be viewed as it provides opportunities for students to engage with unknowns in a well-structured environment which is supported by instructors. Ronald A. Beghetto (2017) also suggested teachers to try lesson-unplanning approach which could have embedded uncertainty into their lesson and students will have more opportunities to practice working through problems with various ways to achieve their learning outcome and they are more likely to take on complex problems. He also suggested to assign complex challenges to students in the classroom in order to prepare them to respond to uncertainty in a more productive manner. Teachers can help students learn to tackle the complex problem by allowing them to learn from successful model. The last strategy is to launch sustainable project in the classroom so that the project can pass on the other cohort of students.

Tauritz. R (2012) expressed an urgent need to enhance 'uncertainty competences' in children due to the fact that they are facing complex (environmental) challenges. She mentioned that young children are already confronted with knowledge uncertainty and teachers need to teach them how to cope with this uncertainty particularly in the knowledge aspect. Traditionally, teachers tried to provide instructions with clarity and efficiency aimed to prevent or eliminate ambiguity (Visser and Visser 2004). This has indirectly shielded students from uncertainty and refrain the students from opportunity to handle uncertainty. In her research framework, Tauritz. R (2012) mentioned that too little or too much of uncertainty block learning, while sufficient uncertainty will motivate learning. She used PBL as an approach to develop an uncertainty action plan where students learn through facilitated problem solving. During PBL activities, students are confronted with a complex real world problem for which there is no definite answer. They worked in groups identifying what they need to learn in order to solve the problem. A plan is made to divide tasks and decide how useful information will be gathered. Facilitator should discuss the inherent uncertainty of planning. During the process students adjust their planning according to the chain of events. During problem solving process, students enhance problem solving skills, decision making, self-directed learning and collaboration skills (Hmelo-Silver 2004). The teacher facilitates learning by providing scaffolding, modelling a positive attitude towards an uncertain, open-ended process and providing feedback (Schmidt *et al*. 2011). In addition to the uncertainty related to content, experienced knowledge uncertainty could also be due to procedural or task ambiguity and complexity. In other words, the instructions aren't clear enough or the learner does not (yet) have the abilities to proceed effectively (Van Merriënboer *et al*. 2003).

Uncertainty In Problem-Based Learning Environment

In a PBL environment, problems are ill structured, crafted in such a way as to purposively fail to provide all the information necessary to develop a solution, and introducing uncertainty about the path toward resolution as well as about the goals (Qin, Johnson, D.W., and Johnson, R.T., 1995). The ill-structured and *problematic* nature of PBL problems is designed to create an imbalance or "cognitive dissonance" (Festinger, 1962) in the learner which motivates a search for explanations. In PBL, engagement in the problem comes before any preparation or formal study. Thus, during problem solving process, uncertainty is a possible disorder in student's cognitive state, which includes missing knowledge about the existence of important concepts or associations between concepts, incorrect association, or mistakes in procedural information (Reggia, 1990). This disorder in cognitive state leads to affective symptoms of anxiety to perform the tasks and lack of confidence in solving the problem. In the PBL environment, students experience uncertainty as they are presented with ill-structured problem which creates a cognitive dissonance (Keller, 1983) or state of disequilibrium. This situation motivates students to commit themselves in questioning, snooping, and searching for information to reduce uncertainty and reenter a state of equilibrium.

Learning Performance in PBL

In traditional lecture-based approach, the most popular assessment is mainly based on examination to measure the acquisition of content knowledge. However, PBL presents some unique challenges for assessment. Due to the fact that PBL is primarily focused on learning to learn and less on mastery of a particular body of knowledge, traditional methods of course assessment may not be very effective (Major, 1999). Thus, an alternative assessment deems necessarily as a better measure of knowledge acquisition for PBL. Using alternative assessment in the case of PBL can help bridge the gap between instruction and assessment. One of these alternative assessments is the authentic assessment which uses tasks developed from realistic activities in the professional world (Nightingale et al., 1996). Authentic assessment task is defined as "complex simulations, case studies, or multi-faceted projects in assessing a range of knowledge, skills and attitudes in the one assessment task" (Nightingale et al., 1996). Luh et al. (2007) have shown that student's attitudes are factors which significantly influence student performance in PBL courses. Giving students the opportunity to evaluate and reflect on their own learning is a key element in PBL. This will also allow the facilitator to help students in assessing their own performance in solving a problem. The self-evaluation of students can be recorded through the learning satisfaction form. An effective assessment tool must be designed to assess the learning outcome from performing the learning task. Some signs of the movement in this direction did exist. Recently, studies have begun to investigate PBL outcomes, such as teamwork or presentation skills, that may not be associated with traditional lecture methods. Cockrell, Caplow, & Donaldson (2000) conducted a study examining students' perspectives on their learning as members of collaborative groups using interpretive methods. They found that the collaborative groups fostered students' sense of ownership of the knowledge that was created over the semester. The researchers also suggested that within the groups, leadership moved from student to student as situations arose and resolved.

PROBLEM STATEMENT

Many universities encourage their faculty to adopt PBL as a student-centered approach in their academic discipline, with the rational that this approach will increase students' satisfaction and enhance their learning ability and lifelong learning skills. However, PBL create anxiety due to lack of prior learning experience and team dynamic issue as well as proper crafted problem scenario. PBL learners face high anxiety to cope with solving challenging problem in the PBL scenario. By adopting an authentic PBL (APBL) model with proper injection of uncertainty into proper crafted ill-defined real world problem and well-planned in all stages of PBL activities, anxiety due to uncertainty can be reduced and learning will then take place which can be measured through the assessment of learning performance.

Authentic Problem-Based Learning (APBL): Facilitator-Learners Partnerships Approach

An Authentic Problem-based learning (APBL) is adopted in this study. APBL emphasizes highly on the facilitator-learners partnership approach. The APBL approach is adapted from the RP's "one-day, One-Problem" PBL model (G. O'Grady et al., 2002) and build around Wilson Problem-solving model (1999). The APBL approach is conducted on Saturday from 8 am to 5 pm to avoid clashing in learners' time-table.

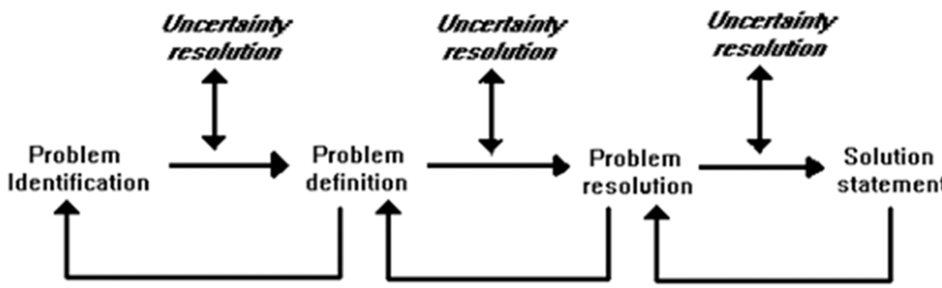
In this APBL model, learners undertaking Physics course will be given a "real world" problem which land them to the following "TIPS" (Wee, 2004) stages:

- Trigger their learning, students will encounter high uncertainty level and curiosity when they receive a problem which is beyond their existing knowledge to tackle it.
- Inquire and information seeking to clarify and identify the problem for uncertainty resolution by stating the problem statement (During Meeting 1 for uncertainty resolution).

- Propose ideas to manage the problem after seeking more information to fill the knowledge gap for uncertainty resolution (during Meeting 2 for further uncertainty resolution)
- Seek and acquire new knowledge alongside with solving the problem (During meeting 3 to compile the acquired knowledge for further uncertainty resolution).

These stages will be closely facilitated by facilitator and taking place in at least 3 meetings, where each meeting serves to reduce uncertainty, as shown in figure 1: The Wilson's Problem solving model.

Figure 1. Wilson's problem-solving model



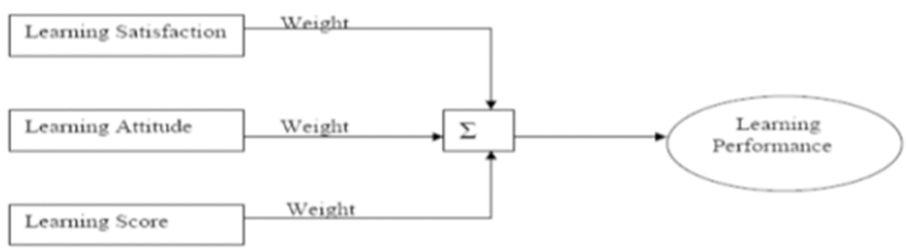
In the context of this research, the uncertainty of PBL learners will be measured to explore the relationship between uncertainty and learning performance while they are carrying out the learning task, which is an ill-structured, purposively designed for student-centered learning activity focusing on a specific domain of knowledge. This learning tasks aims to create a situation for problem definition and problem resolution which motivate the students to achieve specified outcome and learning performance through active information seeking and searching process in interaction with information sources available. Communication among the team member and continuous information seeking and searching characterize moving back and forth between stages due to their uncertainty conditions, a situation of increase or resolution of uncertainty. Facilitator play an important roles to build up the facilitator-learner partnership to continuously providing hints to learners with regards to each of their respective area for information seeking and searching, in the case if learners have queries about certain aspect of information. Facilitator will not give direct answers to learners, instead he will lead the learner to explore the possibilities and direction of obtaining the solution. The APBL approach involves a series of activity carried out by the learners which require each learner to participate in an active learning process and is trained to be independent life-long learner under close facilitation of the facilitator. The significant difference between APBL approach and traditional lecture approach is that APBL learners are heavily and actively involved in information seeking with the facilitation of facilitator to reduce uncertainty, which is a truly facilitator-learners partnerships approach.

Learning Performance in APBL

In this study, learning performance comprise of three constructs, learning satisfaction and learning attitude are subjective measure and learning score is the objective measure. It is defined as the learning satisfaction with regards to the benefits of information seeking process through construction and make sense of the information gathered and knowledge acquisition, and application of knowledge gained to perform the learning task. It is expressed as a function of these indicators, with weightage assigned to the respective indicators as shown in the figure 2.

Figure 2. Expression of learning performance (Loh, K.H, 2010)

Learning Performance = $\sum$ Satisfaction (W), Attitude (W), Score (W)



Learning performance is operationalized as learner's motivation with regards to the benefits of information seeking in helping learning, and knowledge acquisition with regards to knowledge retention and application of knowledge to solve problem that exhibit a positive attitude towards working out the solution in a team effort to achieve the goal. Learning satisfaction is measured using 10-items of self-report measure rated on a scale varying from one being "strongly disagree to five being "strongly agree" on the learner's satisfaction adapted from the usefulness instrument developed and tested by Davis (1989).

Uncertainty in APBL

In the context of this study, uncertainty construct is characterized by behavior in terms of cognitive dimension, affective dimension and physical dimension. Uncertainty is reduced with regards to positive attitude, more focus and understanding of domain knowledge, which is associated with reduce in their affective state in terms of feeling and emotion such as apprehensive, anxiety, confusion and frustration, and physical state of hesitation and perturbation in performing learning task.

Uncertainty level is operationalized as the cognitive state of uncertainty with regards to clearly focused thoughts, associated with the affective state of uncertainty in terms of confidence and positive attitude and physical state of uncertainty level through increased information seeking activities to fill the gap between information required and information processed. The level of uncertainty is measured using a 30-items, self-report measure in a five-point Likert-response format design to assess the uncertainty in cognitive dimension, affective dimension and physical dimension in the questionnaires after they performed a learning task in the APBL environment.

PURPOSE OF THE STUDY

The purpose of this study is to investigate the correlation between uncertainty level and learning performance of the learners after attending an authentic PBL approach for the physics course in American Degree Transfer Program (ADTP) at Taylor's University, Malaysia.

A null hypothesis and its subsidiary null hypotheses were formulated to guide this research.

H_{o1}: There is no statistically significant negative correlation exists between *uncertainty* and *learning performance* of learners in APBL environment.
H_{o1a}: There is no statistically significant negative correlation exists between *uncertainty* and *learning satisfaction* of learners in APBL environment.
Ho_{1b}: There is no statistically significant negative correlation exists between *uncertainty* and *learning attitude* of learners in APBL environment..
H_{01c}: There is no statistically significant negative correlation exists between *uncertainty* and *learning score* of learners in APBL environment.

METHODOLOGY

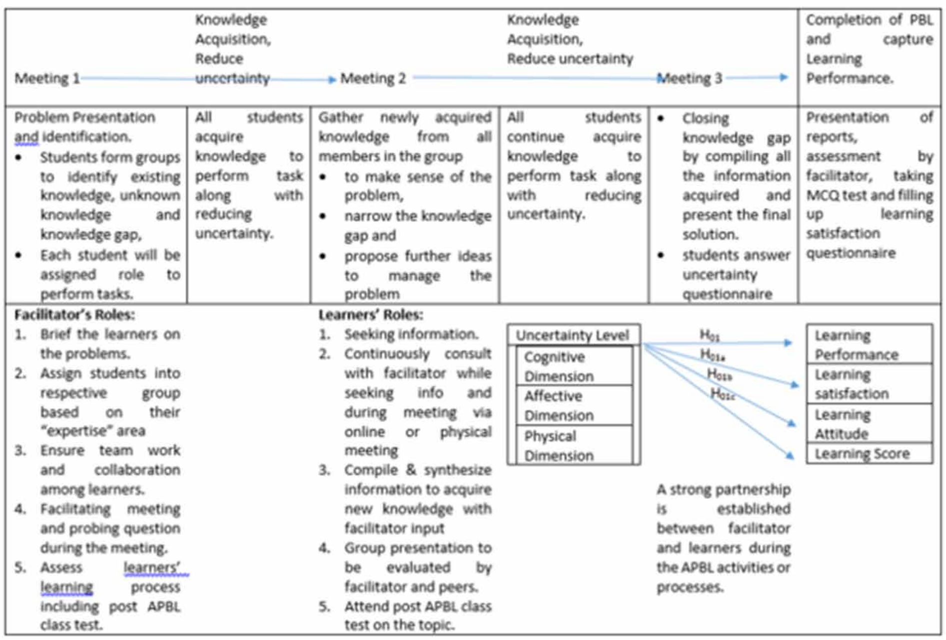
The Sample

This research recruited 78 university students who registered to undertake Physics course in the Fall 2017 semester in the American Degree Transfer Program at Taylor's University to participate in this study. The facilitator spent 20 minutes to brief the APBL scenario to the students and started to divide all students in groups of five to six students. The groups of students were then given some time to discuss and formulating their problem statement and to seek some verification from facilitator so as to ensure that they are at the right track. All participants were given the questionnaire on uncertainty and learning satisfaction to fill out after they completed the APBL tasks and submitted together with the APBL report. The participants will be tested on the domain related to APBL problem with Multiple Choice Questions one week after the APBL session. The details of these activities in APBL is outlined in the research framework in the next section

Research Framework

As the research will look into relationship between learner's uncertainty level and the learning performance in their problem solving process while performing a learning task in APBL environment, it is guided by the research framework which adapted the Wilson Problem Solving Model, as shown in Figure 3.

Figure 3. Research framework of relationship between uncertainty level and learning performance in authentic PBL environment



A summary of the steps involved in a typical APBL session heavily focus on facilitator-learners partnerships is listed below:

During and following the 1st meeting:

- Facilitator organize brainstorming to explore issues in an "ill-structured" problem posted.
- Learners perceive uncertainty existed in the problem, as purposively crafted and created by facilitator
- Learners develop the problem statement agreed upon based on group analysis, and notify the facilitator on this problem statement to ensure they are in the right track.
- Facilitator throw out probing questions for learners to develop plan to solve problem.
- Learners will then list out possible solutions and order them from the strongest to the weakest.
- Facilitator points the learners to seek and search for possible resources: Experts, books, web sites.
- Learners begin their research by seeking reliable information to fill in missing gaps.

During and following the 2nd meeting:

- Learners acquire the information needed.
- Facilitator facilitate the learners in the group to ask probing questions among the group member so as to analyze and evaluate the information,

During the 3rd meeting

- Facilitator allows learners to synthesize and organize the information. Learners meet to interpret and integrate information into existing knowledge base.
- Learners are encouraged to communicate and present findings and/or recommendations among themselves.
- All learners in the group write up the solution with its supporting documentation.
- Learners present new knowledge. Learners in every group are culminating presentation of the solution and performance to convince as well as help other learners to learn.
- Facilitator assesses the individual participants during the entire PBL process on the attitude, skills and knowledge.
- Learners assess the self-evaluation on the learning satisfaction as well as their uncertainty level
- Facilitator capture learners' knowledge acquisition and retention in examination after some time lapse.

Obviously, there exists a very strong facilitator-learners partnership during the learning activities carry out throughout the processes in the APBL.

Research Design

This study adopts correlational research design with 78 Physics students participated in the study. The questionnaire consists of 30 items of uncertainty constructs and 10 items on satisfaction of learning experience in 5 points Likert scale. All participants were tested on their uncertainty level and satisfaction in learning experience about the learning task at the end of the APBL process They were given the questionnaire on uncertainty and learning satisfaction to fill out after they completed the APBL tasks and submitted together with the APBL report.. Besides, learning attitude is measured using 8-items instrument to evaluate student's attitude by facilitator during the whole PBL activities inclusive the assessment for the report presentation of the learning task on a scale varying from one being "unsatisfactory" to five being "exceptionally satisfactory", together with the marks assigned to the report of the solution of APBL learning task.

Learning score is the assessment on a test sheet which consists of 15 multiple choice questions designed for the topics on course unit conducted in APBL. It is a test consists of multiple choice questions on the related topic and administered 1 week after the authentic problem-based learning activities and captured as the learning score.

Instruments

The variables in this study are Learners' uncertainty level and Learning performance. A carefully crafted "ill-structured" problem scenario that triggers the learning activity is given to all participants, with 20 minutes perusal time. A posttest instrument consists of 30 items of uncertainty construct which record their thinking, feeling and action in terms of cognitive dimension, affective dimension and physical dimension in 5 points Likert scale, together with additional 10 items on satisfaction of learning experience is administered to all students at the end of the APBL process. The variables can be computed using SPSS to determine the mean score of the uncertainty level in each item attributed to the uncertainty construct and learning performance. The Pearson's Correlational analysis was carried out on these variables which served to reject and fail to reject the null hypotheses.

FINDINGS

The objective of this study is to investigate the relationship between APBL learners' uncertainty level and learning performance. In order to examine whether this objective is achieved, it is imperative to test the null hypothesis and the associated subsidiary null hypotheses.

Testing of Hypothesis H_{01}

H_{o1}: There is no statistically significant negative correlation exists between *uncertainty* and *learning performance* of learners in APBL environment.

A Pearson product-moment correlation was computed to assess correlation between uncertainty and learning performance of all learners after APBL session. The statistical analysis revealed that these variables were, as predicted, negatively related and that the correlation was statistically significant ($r = -0.19$, $n = 78$, $p<0.05$, one-tailed). Thus, null hypothesis H_{01} was rejected in favor of its alternative hypothesis. It follows that there is a statistically significant, but weak negative correlation between uncertainty and learning performance in APBL environment. This statistical analysis revealed that lower uncertainty level corresponds to higher learning performance.

Testing of Hypothesis H_{01a}

H_{o1a}: There is no statistically significant negative correlation exists between *uncertainty* and *learning satisfaction* of learners in APBL environment.

A Pearson product-moment correlation coefficient was computed to assess correlation between uncertainty and learning satisfaction of all learners after APBL session. There was statistically significant negative correlation between the two variables ($r = -0.306$, $n = 78$, $p < 0.05$ one-tailed). Thus, null hypothesis H_{o1a} was rejected in favor of its alternative hypothesis. Overall, there is a moderate, statistically significant negative correlation exists between uncertainty and learning satisfaction. This statistical analysis revealed that lower uncertainty level corresponds to higher learning satisfaction.

Testing of Hypothesis H_{01b}

H_{01b}: There is no statistically significant negative correlation exists between *uncertainty* and *learning attitude* of learners in APBL environment.

A Pearson product-moment correlation was computed to assess correlation between uncertainty and learning attitude of all learners after APBL session. There was a statistically significant negative correlation between the two variables ($r = - 0.213$, $n = 78$, $p < 0.05$, one-tailed). Thus, null hypothesis H_{o1b} was rejected in favor of its alternative hypothesis, which stated that there is a statistically significant but weak negative correlation exists between uncertainty and learning attitude in PBL environment. Overall, this statistical analysis revealed that lower uncertainty level corresponds to higher learning attitude.

Testing of Hypothesis H_{01c}

H_{01c}: There is no statistically significant negative correlation exists between *uncertainty* and *learning score* of learners in APBL environment.

A Pearson product-moment correlation coefficient was computed to assess the correlation between the uncertainty and learning score of all learners after a PBL session. There was no statistically significant negative correlation between the two variables ($r = .148$, $n = 78$, $p > 0.05$. Thus, this statistical analysis has failed to reject the null hypothesis H_{1c}. Overall, there is no statistically significant negative correlation exists between uncertainty level and learning score. Instead, the finding has indicated that uncertainty is positively correlated to the learning scores, which exhibit an unanticipated result (Learning score was obtained after some time lapse). The explanation to this unanticipated result will be discussed in next section.

The results derived from Pearson product-moment correlation analysis were summarized in a table form, as shown in Table 1.

Table 1. Results from analysis of pearson product-moment correlation

Null Hypotheses (Pearson's r)	Results	Alternative Hypotheses
H_{o1}: There is no statistically significant negative correlation exists between *uncertainty* and *learning performance* of learners in APBL environment.	$r = -0.19$, $n = 78$, $p<0.05$, one-tailed H_{01} was rejected in favor of H_1	H_1: There is statistically significant negative correlation exists between *uncertainty* and *learning performance* of learners in APBL environment.
H_{o1a}: There is no statistically significant negative correlation exists between *uncertainty* and *learning satisfaction* of learners in APBL environment.	$r = -0.306$, $n = 78$, $p < 0.05$ one-tailed H_{01a} was rejected in favor of H_{1a}	H_{1a}: There is statistically significant negative correlation exists between *uncertainty* and *learning satisfaction* of learners in APBL environment.
H_{01b}: There is no statistically significant negative correlation exists between *uncertainty* and *learning attitude* of learners in APBL environment.	$r = - 0.213$, $n = 78$, $p < 0.05$, one-tailed H_{01b} was rejected in favor of H_{1b}	H_{1b}: There is statistically significant negative correlation exists between *uncertainty* and *learning attitude* o of learners in APBL environment.
H_{01c}: There is no statistically significant negative correlation exists between *uncertainty* and *learning score* of learners in APBL environment.	$r = .148$, $n = 78$, $p > 0.05$, one-tailed Fail to reject H_{01c}	

The Product Moment correlation coefficient analysis revealed that there was a statistically significant negative correlation between learning satisfaction, learning attitude and learning performance and the total uncertainty of the students. However, a contradictory positive correlation between uncertainty level and learning scores was observed. This correlation was opposite to the anticipated negative correlation between uncertainty and learning score. Instead, a statistically significant positive correlation between uncertainty and learning score was found.

This result indicated that the evaluation method of learning process in APBL must stress on continuous assessment on affective and attitudinal aspect as well as their understanding rather than multiple choice questions at the end of APBL session. Structured short-answer questions could be a better alternative to the APBL assessment as APBL stresses on critical thinking and has a potential to structure knowledge which optimise the knowledge acquisition and retention.

CONCLUSION

Traditional lecture approach treated teaching and learning as purposefully reducing the uncertainty of students. This approach may undermine the process of learning and incapacitates learner's inquisitiveness and initiative. However, APBL incorporates uncertainty naturally as a source of intrinsic motivation and a stimulus to learning. APBL learners will be stimulated by cognitive dissonance when they encounter an ill-structured problem. The associated uncertainty acts as a catalyst which provokes real learning. They will begin to seek for information to fill the gaps between what they know in their existing knowledge base and what they do not know. This activity accompanies the appearance of reorganization, stability, and progressive development or learning (Germana & Lancaster, 1995). Thus, the uncertainty level was negatively correlated to the learning satisfaction, learning attitude and learning performance. However, the low effect size of positive correlation between uncertainty level and learning score illustrate that multiple choice questions was the inappropriate testing instrument used in PBL evaluation.

The contradictory positive correlation between uncertainty level and learning scores was really unanticipated. It is known that learning scores were the marks obtained by the learners during the examination on the topics related to the APBL problems. This examination was administered one week later after the PBL activity. It was in the forms of multiple choice questions which was the preferred format of evaluation in traditional lecturing approach. Apparently, this format of evaluation was not suitable for APBL because APBL strategy stresses on critical thinking and has a potential to structure knowledge so that acquisition and recall are optimised. Moreover, APBL learners develop self-directed learning skills, which motivate them to better express the structured knowledge that they have acquired through APBL activity.

Findings from the research indicated that preferred assessment method used in the traditional lecture approach did not show evidence of negative correlation between learning as measured by the assessment method and uncertainty level. This result led to the implication that the evaluation method of learning process in APBL must stress on continuous assessment on affective and attitudinal aspect as well as their understanding rather than multiple choice questions at the end of APBL session. Structured short-answer questions could be a better alternative to the APBL assessment as APBL stresses on critical thinking and has a potential to structure knowledge which optimise the knowledge acquisition and retention.

Pearson's Product Moment correlation coefficient provide evidence of relationship and strength of association between uncertainty and learning performance and its associated subsidiary constructs in this study.

The Product Moment correlation coefficient analysis revealed that there was a statistically significant negative correlation between learning satisfaction, learning attitude and learning performance and the total uncertainty of the learners. However, a contradictory positive correlation between uncertainty level and learning scores was observed. This correlation was opposite to the anticipated negative correlation between uncertainty and learning score. Instead, a statistically significant positive correlation between uncertainty and learning score was found.

REFERENCES

Agor, W. H. (1986). *The logic of intuitive decision-making: A research based for top management*. Westport: Quorum Books.

Aiginger, K. (1987). *Production and decision theory under uncertainty*. Oxford: Basil Blackwell.

Allison, G. (1971). *Essence of decision: explaining the cuban missile crisis*. Boston: Little, Brown, and Co.

Azila, N. M. A., Sim, S. M., Tan, C. P. L., & Alhady, S. F. (1999). Problem-based learning (PBL): Making an impact in education. *Journal of University of Malaya Medical Centre*, *4*(2), 94–98.

Baird, B. F. (1989). *Managerial decisions under uncertainty*. New York: John Wiley & Sons, Inc.

Barnard, C. I. (1938). *The functions of the executive*. Cambridge: Harvard University Press.

Barr, R., & Tagg, J. (1995). From teaching to learning: A new paradigm for undergraduate education. *Change*, *27*(6), 12–25. doi:10.1080/00091383.1995.10544672

Barrett, T. (2017). *A New Model of Problem-based learning: Inspiring Concepts, Practice Strategies and Case Studies from Higher Education*. Maynooth: AISHE.

Beghetto, R. A. (2017). Inviting uncertainty into the classroom. *Educational Leadership*, *75*, 20–25.

Borhan, M. T. (2012). Problem-based Learning (PBL) in Malaysian Higher Education: A Review of Research on Learners' Experience and Issuesof Implementation. *ASEAN Journal of Engineering Education*, *1*(1), 48–53.

Boud, D., & Feletti, G. I. (1991). *The challenge of problem-based learning*. London: Kogan.

Boyer Commission Report. (1998). *Reinventing undergraduate education: A blueprint for America's research universities*. New York: The Carnegie Foundation for the Advancement of Teaching.

Brooks, J. G., & Brooks, M. G. (1993). *In search of understanding: The case for constructivist classrooms*. Alexandria: Association for Supervision and Curriculum Development.

Cockrell, K. S., Caplow, J. A. H., & Donaldson, J. F. (2000). A Context for Learning: Collaborative groups in the problem-based learning environment. *Review of Higher Education*, *23*(3), 347–363. doi:10.1353/rhe.2000.0008

Covey, S. R., Roger, A. M., & Rebecca, R. (1994). *First Things First*. New York: Simon and Schuster.

Cross, K. P. (1998). A proposal to improve teaching or what taking teaching seriously should mean. *AAHE Bulletin*, *39*(1), 9–14.

Cynthia, L. S. (2015). *The futures of learning 3: What kind of pedagogies for the 21st century?* Education, Research and Foresight, Working Paper 15.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *Management Information Systems Quarterly*, *13*(3), 319–340. doi:10.2307/249008

Einhorn, H. J., & Hogarth, R. M. (1986). Decision making under ambiguity. *The Journal of Business*, *59*(S4), 225–250. doi:10.1086/296364

Ewell, P. T. (1997). Organizing for learning: A new imperative. *AAHE Bulletin*, *50*(4), 3–6.

Festinger, L. (1962). Cognitive dissonance. *Scientific American*, *210*(4), 93–102. doi:10.1038cientificamerican1062-93 PMID:13892642

Germana, J., & Lancaster, R. (1995). Brain dynamics, psychophysiological uncertainty, and behavioral learning. *Integrative Physiological and Behavioral Science*, *30*(2), 138–150. doi:10.1007/BF02691682 PMID:7669700

Hamouda, O., & Rowley, R. (1996). *Probability and Economics*. London: Routledge.

Hassan, Yusof, Hamid, Hassim, Aziz, & Hassan. (2004, December). *A review and survey of problem-based learning application in engineering education*. Paper presented at the Conference on Engineering Education, Kuala Lumpur.

Hey, J. D. (1993). Dynamic decision making under uncertainty: An experimental study of the dynamic competitive firm. *Oxford Economic Papers*, *45*(1), 58–82. doi:10.1093/oxfordjournals.oep.a042084

Hmelo-Silver, C. E. (2004). Problem-based learning: What and How Do Students Learn? *Educational Psychology Review*, *16*(3), 235–266. doi:10.1023/B:EDPR.0000034022.16470.f3

Horvitz, E. J., & Barry, M. (1995). Display of information for time-critical decision making. In *Uncertainty in Artificial Intelligence: Proceedings of the Eleventh Conference* (pp. 296–305). San Francisco: Morgan Kaufmann.

Huettel, S. A., Song, A. W., & McCarthy, G. (2005). Decisions under uncertainty: Probabilistic context influences activation of prefrontal and parietal cortices. *The Journal of Neuroscience*, *25*(13), 3304–3311. doi:10.1523/JNEUROSCI.5070-04.2005 PMID:15800185

Janis, I. L., & Mann, L. (1977). *Decision making: A psychological analysis of conflict, choice and commitment*. New York: Free Press.

Johnson. (2011). *Helping Students Deal with Uncertainty in the Classroom*. Edutopia.

Keller, J. M. (1983). Motivational Design of Instruction. In C. M. Reigeluth (Ed.), *Instructional-Design Theories and Models: An Overview of Their Current Status* (pp. 383–429). New York: Lawrence Erlbaum Associates.

Lee, V. S. (1998). *The uses of uncertainty in the college classroom. Essays on Teaching Excellence, 12(1)*. Fort Collins, CO: POD Network in Higher Education.

Loh, K. H. (2010). *The impact of information literacy skills training on uncertainty reduction, learning performance and academic self-efficacy in a problem-based learning (PBL) environment* (Unpublished doctoral dissertation). International Islamic University of Malaysia, Kuala Lumpur.

Luh, S. P., Yu, M. N., Lin, Y. R., Chou, M. J., Chou, M. C., & Chen, J. Y. (2007). A Study on the personal traits and knowledge base of Taiwanese medical students following problem-based learning instructions. *Annals of the Academy of Medicine, Singapore*, *36*(9), 743–748. PMID:17925982

Major, C. H. (2002). Problem-based learning in general education at Samford University: A case study of changing faculty culture through targeted improvement efforts. *The Journal of General Education*, *51*(4), 235–256. doi:10.1353/jge.2003.0015

McCalla, R. B. (1992). *Uncertain perceptions. U.S. Cold War crisis decision-making*. Ann Arbor: University of Michigan Press.

McKeachie, W. J., Pintrich, P. R., Lin, Y. G., & Smith, D. A. F. (1986). *Teaching and Learning in the College Classroom: A Review of the Research Literature*. Ann Arbor: University of Michigan Press.

Mokhtar, S., & Abu Bakar, Z. (2003). PBL Implementation in Computer Science and Information Technology. *Journal of Problem-based Learning*, *2*(1), 1–9.

Nigel, H. (1993). The role of emotions in multi-organizational decision-making. *The Journal of the Operational Research Society*, *44*(6), 613–623. doi:10.1057/jors.1993.102

Nightingale, P., Te Wiata, I., Toohey, S., Ryan, G., Hughes, C., & Magin, D. (1996). *Assessing learning in universities*. Sydney: UNSW Press.

Nutt, P. C. (1990). *Making tough decisions: tactics for improving managerial decision-making*. San Francisco: Jossey-Bass Publishers.

O'Grady, G. (Ed.). (2012). *One-Day, One-Problem: An Approach to Problem-based Learning*. Springer. DOI doi:10.1007/978-981-4021=75-3_1

Perry, W. G. (1970). *Forms of intellectual and ethical development in the college years: A scheme*. New York: Holt, Rinehart & Winston.

Qin, Z., Johnson, D. W., & Johnson, R. T. (1995). Cooperative versus competitive efforts and problem-solving. *Review of Educational Research*, *65*(2), 129–143. doi:10.3102/00346543065002129

Reggia, J. A. (1990). *Abductive inference model for diagnostic problem solving*. New York: Springer-Verlag.

Savery, J. R., & Duffy, T. M. (1995). Problem-based learning: An instructional model and its constructivist framework. In B. Wilson (Ed.), *Constructivist learning environments: Case studies in instructional design* (pp. 135–148). Englewood Cliffs, NJ: Educational Technology Publications.

Schmidt, G., Rotgans, J., & Yew, E. (2011). The process of problem-based learning: What works and why. *Medical Education*, *45*(8), 792–806. doi:10.1111/j.1365-2923.2011.04035.x PMID:21752076

Shortlife, E. H., Bamet, G. O., Cimino, J. J., Greenes, R. A., & Patel, V. L. (1996). Collaborative medical informatics research using the internet and the world wide Web. In *Proceeding of the AMIA Annual Fall Symposium in Washington* (pp.125-129). Philadelphia: Hanley & Belfus.

Simon, H. A. (1947). *Administrative Behaviour: A study of decision making processes in administrative organization*. New York: Free Press.

Tauritz, R. (2012). How to handle knowledge uncertainty? Learning and teaching in times of accelerating change. In *Learning for Sustainability in times of accelerating change*. Wageningen: Wageningen Academic Publishers. doi:10.3920/978-90-8686-757-8_19

Van Asselt, M. (2000). *Perspectives On Uncertainty And Risk. The Prima Approach to Decision Support*. Dordrecht: Kluwer Academic Publishers. doi:10.1007/978-94-017-2583-5

Vickers, D. (1994). *Economics and the Antagonism of Time*. Ann Arbor: University of Michigan Press. doi:10.3998/mpub.14114

Visser, J., & Visser, Y. L. (2004). Ambiguity, cognition, learning, teaching, and design. *TechTrends*, *48*(1), 40–43. doi:10.1007/BF02784863

Weber, E., & Milliman, R. (1997). Perceived risk attitudes: Relating risk perception to risky choice. *Management Science*, *43*(2), 123–144. doi:10.1287/mnsc.43.2.123

Wee, K. N., Kek, Y. C., Silva, G., & Seah, T. H. (2000). *Tried & tested: issues & implications for educators in problem-based learning: relearning from the learners' perspective*. Paper presented at the 2nd Asia Pacific conference in Problem-based Learning organised by Temasek Polytechnic, Singapore.

Wee, K. N. L. (2004). *Jump Start Authentic Problem Based Learning*. Singapore: Prentice Hall Pearson Education South Asia Pte. Ltd.

Wilson, T. D. (1999). Model in information behavior research. *The Journal of Documentation*, *55*(3), 249–270. doi:10.1108/EUM0000000007145