IDENTIFYING GAPS AND PRIORITY NEEDS OF INSRUCTIONAL DESIGN FOR SAFETY AWARENESS LEARNING SYSTEM FOR UNDERGRADUATE STUDENTS MAJORING IN GEMS AND JEWELRY*

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Abstract: The gems and jewelry industry play a significant part in Thailand's economic development. Yet, the concerns towards welfare and safety of the jewelry manufacturing workers have been neglected and remains unsolved. Reviews of literature suggest that developing the adaptive procedural simulated learning system based on four-component instructional design to promote safety awareness is an efficient approach to reduce safety risk. The learning system could be implemented to undergraduate studies to equip them with safety awareness before they enter the workforce. The purposes of this study were 1) to investigate the needs for developing safety awareness learning system, 2) to explore the students' current and desirable state of perceived importance regarding instructional design and 3) to prioritize students' needs and expectations to design a learning system that is motivating and interesting to them. Validated questionnaires were collected from 355 undergraduate students majoring in gems and jewelry in Thailand. The result shows that current state of student's perceived importance of instructional design was at medium level (Mean = 2.96, SD = 0.69) while the desirable state was at the high level (Mean = 4.00, SD = 0.72). The gaps between the current and desirable state were further analyzed using $PNI_{modified}$ and revealed the top five priority needs for system design as followed: 1) ability to evaluate and analyze learner's prior knowledge before each topic, 2) flexibility in arranging learning topics, 3) flexibility in selecting activities that achieve same outcome, 4) ability to adapt difficulties according to student's needs, and 5) ability to demonstrate necessary operating skills.

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Introduction

Thailand's gems and jewelry industry have generated a substantial amount of revenue to different business sectors, from the industrial sector, community business, OTOP, to personal scale. Even though this industry may seem like a great potential for growth and personal well-being, yet the labor welfare of the jewelry manufacturing working has been underprivileged. There were close to 2,000 cases of work-related accidents in the jewelry industry reported in 2013 to 2017 (SSO, 2017). This number confirms that working condition and welfare of the workers in this industry is quite disturbing

Many pieces of research exhibited that the major causes of work-related accident are, not from unsafe working environment, but from the errors of workers themselves (Sole, Musu, Boi, Giusto, & Popescu, 2013; Sonprom, 2012; Zhao & Lucas, 2014) Consequently, the appropriate and most efficient approach for accident prevention is to empower the workers with knowledge regarding work safety and risks (Guastello, 1993). This can be achieved by developing an appropriate learning system that enhance learner's safety awareness. According to Burke et al. (2006), training for safety is more effective when the program consists of behavioral modeling and a substantial amount of practice for learner. A good example of such program is training with simulation, where the simulated environment is designed to let the learner focus on the learning task without extraneous factors (Analoui, 1993). In order to achieve optimal learning efficiency, the training program should be flexible according to the learner's need (Salden, Paas, & van Merriënboer, 2006). As a result, to provide the instructional design for the individual scale, the learning system should be adaptive to accommodate different learners (Jevremović & Vasić, 2010). And in order to promote knowledge transfer from the training, the learning system should be designed based on Four-Component Instructional Design (4C/ID) model (van Merriënboer & Kirschner, 2018). The four components are 1) Learning Tasks which is sequence of whole tasks that is related to the actual working objectives, 2) Supportive Information which is the knowledge or the theory that helps the learners performing the tasks, 3) Procedural Information which is the knowledge needed to solve parts of the task, and 4) Part-Task Practice which is repetition and drill session that encourage the learner to perform certain task automatically.

As stated above, one of the most effective ways to prevent accidents in the jewelry industry is to develop a learning system to promote safety awareness.

The learning system should be implemented as early as during undergraduate studies to empower the learners with safety awareness well before they enter the workforce. This would create new norms of safe working culture and therefore reduce the risk of accidents in the Jewelry industry in the future. However, requirements and guidelines in developing such learning system are still needed. This paper will investigate the students' current and desirable state of importance regarding instructional design for safety awareness learning system and prioritize students' needs and expectations to design a learning system that is motivating and interesting to the students to create the learning system that is efficient, effective, and meets the satisfaction of the learners.

Objectives

The purposes of this study were

1. To investigate the needs for developing safety awareness learning system.
2. To explore the students' current and desirable state of perceived importance regarding instructional design for safety awareness learning system.
3. To prioritize students' needs and expectations to design a safety awareness learning system that is motivating and interesting to the students.

Conceptual Framework

In this paper, safety awareness refers to the state of being aware of safety issues, and of potential hazards to the oneself and others in the workplace, including prevention and protection of those issues. Safety awareness can be categorized into three categories: 1) Awareness of hazardous working-condition, 2) Awareness of responsibility, and 3) awareness of rules and regulations.

To develop the learning system that promotes safety awareness, three key components in the design framework are considered, which are Adaptive Learning, Procedural Simulation, and Four-component Instructional Design (4C/ID). The components are elaborated in the context below.

Adaptive learning environment refers to the learning environment that has the ability to follow the learner's activities, analyze and interpret them, conclude and adjust the environment, and provide the learner with suitable knowledge and learning process (Jevremović & Vasić, 2010). The theory framework of adaptive learning can be conceptualized within the information system wherein the informer is the instructor, the client is the student, and the rule-based adaptive engine both informs and is informed by interaction with the client Adaptive learning system is essentially the instruction management system that responds to the requirement of learners, generally consisting of

three different components as followed: 1) Domain Knowledge Module that stores contents of the course, 2) Student Model Module that keeps track of learner's progress, and 3) Adaptive Engine Module that analyzes and interprets learner's knowledge and progress. (Murray et al., 2015).

Procedural Simulation is the simulated learning environment created for instruction and training (Alessi & Trollip, 2001) that allows learners to focus on the instruction without disruption from extraneous factors (Analoui, 1993). Simulation also allows learner to intuitively solve problems without risks of being in physical danger (Alessi, 2000). When applying simulation as an educational method, not only it improves learners' knowledge and operative skills, but also results in high levels of satisfaction from trainees and instructors (Nestel, Groom, Eikeland-Husebø, & O'Donnell, 2011) Heinich, Molenda, Russell, and Smaldino (2002) suggests that effective simulation consists of three elements which are 1) Model (storyline), 2) Failure Staging, and 3) Simulation Mentor.

Four-component Instructional Design (4C/ID) refers to the instruction design that consists of 4 main components as followed (Van Merriënboer, Clark, & De Croock, 2002) 1) learning task which is authentic whole-task that integrates skills, knowledge, and attitudes of the learner, 2) supportive information which is the information helpful for the learner to perform the problem-solving and reasoning aspects of the learning tasks, 3) procedural information which is the "how-to" information that is displayed only at the moment it is needed, and 4) part-task practice which is the practice items provided to learners to help them reach a very high level of automaticity for selected routine aspects of a task.

Methodology

Procedure

A questionnaire survey was conducted to investigate student's safety awareness training experience, and to explore and identify the gap between the current and desirable states of student's perceived importance regarding instructional design for safety awareness learning system. The gap was then analyzed using $PNI_{modified}$ revealing the priority needs for designing the learning system.

Participants

The participants of this research were 355 undergraduate students majoring in gems and jewelry in Thailand. Given a population of 1,361 undergraduate students majoring in gems and jewelry in Thailand, the number participants in this research exceeded the minimum sample of 311 students which was

determined by Yamane's formula (Yamane, 1973) with 95% confidence level at the level of error +-5%.

Instrumentation

The 4-part survey questionnaire was designed and validated by experts. The questionnaire covers student's basic information, experience in training for safety awareness, experience in learning with adaptive procedural simulated learning system based on four-component instructional design (4C/ID), and their perceived importance in instructional design for safety awareness learning system.

Findings

The results of survey are divided into 4 different parts

Part 1 The basic information of the students

Part 2 The students' experience in safety awareness training

Part 3 The students' experience in learning with adaptive procedural simulated learning system based on four-component instructional design (4C/ID)

Part 4 The students' current and desirable state of perceived importance regarding instructional design and priority need index of instructional design for safety awareness learning system

Part 1 The basic information of the students

The participants of this research were 355 undergraduate students, consisting of 271 females and 84 males, interpreted as 76.3 and 23.7 percentage respectively. Of these participants, 57 were freshmen (16.1%), 122 were sophomores (34.4%), 112 were juniors (31.5%), and 64 were seniors and above (18.0%). The data showed that most of the participants, comprising of 211 students (59.4%), were from Burapha University, while 106 participants (29.9%) were from Srinakharinwirot University, and 38 participants (10.7%) were from Rajamangala University of Technology Rattanakosin.

The results shown that most of students, 292 participants (82.3%), have access to computer stations at their universities. 306 participants (86.2%) stated that they have personal computers or laptop, while 325 participants (91.5%) stated that they have tablet or smartphone. The results are illustrated below in Table 1.1

Table 1.1 *Basic information of the students*

Variable	Information	Amount	Percentage
Gender	Male	84	23.7
	Female	271	76.3
College years	Freshman	57	16.1
	Sophomore	122	34.4
	Junior	112	31.5
	Senior and above	64	18.0
University	Burapha University	211	59.4
	Srinakharinwirot University (SWU)	106	29.9
	Rajamangala University of Rattanakosin (RMUTR)	38	10.7
Access to university computer	Yes	292	82.3
	No	63	17.7
Own laptop or PC	Yes	306	86.2
	No	49	13.8
Own tablet or smartphone	Yes	325	91.5
	No	30	8.5

Upon further investigation, the result showed that, among those 49 participants who do not own personal computers or laptop, 42 of them (85.7%) had access to university computers, leaving only 7 individuals (14.3%) who claimed they do not have access to university computer.

Part 2 The students' experience in safety awareness training

The research found that 224 students (63.1%) believed they have not been trained regarding work safety. Only 131 participants (36.9%) stated that they had been taught about safety in jewelry making. Further investigation found that the average overall safety awareness level was at medium range (Mean = 2.84, SD = 0.60) among those who stated that they had been trained about work safety. To confirm, five aspects of ability to work with safety were further considered. The five aspects were 1) ability to prevent and avoid accidents, 2) ability to detect hazardous situations, 3) ability to forecast accidents, 4) discipline to follow rules and regulations, and 5) awareness of work safety. The students self-rated themselves at medium level to all aspects of ability to work with safety (Mean = 2.85, 2.76, 2.84, 2.91, 2.85; SD = 0.81, 0.88, 0.82, 0.78, 0.72 respectively), as listed below in Table 2.1 and 2.2.

Table 2.1 *The students' experience in learning about work safety*

Experience in safety awareness training	Amount	Percentage
Yes	131	36.9
No	224	63.1

Table 2.2 *Abilities to work with safety among students' who had been trained in work safety*

Abilities to work with safety	Mean	SD
Ability to prevent and avoid accidents	2.85	0.81
Ability to detect hazardous situations	2.76	0.88
Ability to forecast accidents	2.84	0.82
Discipline to follow rules and regulations	2.91	0.78
Awareness of work safety	2.85	0.72
Overall	2.84	0.60

Part 3 The students' experience in learning with adaptive procedural simulated learning system based on four-component instructional design (4C/ID)

The study on students' experience in learning with adaptive procedural simulated learning system based on four-component instructional design (4C/ID) found that when considering learning methods separately, 228 students (64.2%) have learned from computer-based adaptive instruction, 126 students (35.5%) have learned from computer simulation, and 258 students (72.7%) have learned by performing learning tasks. However, when integrated those three methods together, 261 students (73.5%) have never studied with the proposed learning system. The results are shown in Table 3

Table 3 *The students' experience in learning with adaptive procedural simulated learning system based on four-component instructional design (4C/ID)*

Learning Method	Experience	Amount	Percentage
Learned from computer-based adaptive instruction	Yes	228	64.2
	No	127	35.8
Learned from computer simulation	Yes	126	35.5
	No	229	64.5
Learned by performing learning tasks	Yes	258	72.7
	No	97	27.3
Learned from a learning system that integrated three methods above	Yes	94	26.5
	No	261	73.5

Part 4 The students' current and desirable state of perceived importance regarding instructional design and priority need index of instructional design for safety awareness learning system

Instructional design strategies were abstracted from the frameworks of adaptive instruction, procedural simulation, and 4C/ID. The participants were asked to rate, according to their perception, the level of current implementation of those strategies in their studies. The result found that the overall students' perception towards the implementation of those instructional design strategies at current state was at medium level (Mean = 2.96, SD = 0.69). The instructional design strategy perceived as being implemented at highest level at current state was learning from system that enables the learner to conclude the lesson (Mean = 3.17, SD =1.10). The second highest instructional design strategy perceived as being implemented was learning from system that can restart the lesson at any time (Mean = 3.12, SD = 1.09). Learning from system that explains steps or guidelines of the working process before lesson was perceived as third highest level of implementation (Mean = 3.10, SD = 1.02). Learning from system that suggests hints, alternatives or further useful information during the lesson, and learning from system that provides high level of supports during the beginning of the lesson then reduces the supports when the learner has mastered the skill were perceived as fourth and fifth highest level of implementation (Mean = 3.08, 3.05 and SD = 1.01, 0.93 consecutively).

The participants were also asked to rate their desired instructional design strategies in a safety awareness learning system. The result found that overall desirable state of perceived importance of instructional design strategies was at high level (Mean = 4.00, SD = 0.72). The instructional design strategy that the students desired most was learning from system that enables the learner to conclude the lesson (Mean = 4.15, SD = 1.02), while second most desired strategy is learning from system that can restart the lesson at any time (Mean = 4.10, SD = 0.93). In addition, learning from system that explains steps or guidelines of the working process before lesson, and learning from system that can analyze the solution and guide the learner to solve the problem, were perceived as third and fourth most desired instructional design strategies (Mean = 4.06, 4.04 and SD = 0.98, 0.93 consecutively). Lastly, learning from system that has constant open access to supportive information needed for the lesson was perceived as fifth most desired instructional design strategy (Mean = 4.04, SD = 0.96).

When analyzing the difference of the average of the current and desirable state of perceived importance of instructional design for safety awareness learning system, it was found that all items of the desirable state of instructional design

are significantly higher than the current state statistically at .05 level. The difference of current and desirable state was further analyzed with priority needs index ($PNI_{modified}$) (Wongwanich, 2007) to find out the instructional design strategies that ought to be prioritized in safety awareness learning system design. The result revealed top five priorities as followed. The priority was to design the learning system that can evaluate and analyze learner's prior knowledge level before each topic. It is also important to design the learning system that allows learner to control the topic sequence and allows learner to select any activity that achieves same outcome, as these strategies were ranked number two and three consecutively. The fourth and fifth priorities were to design the learning system that adapts the difficulty of lesson according to learner's need and demonstrates necessary skills before practice. The current and desirable state of students' perceived importance regarding instructional design, as well as the priority needs index, are illustrated in table 4.

Table 4 *The students' current and desirable state of perceived importance regarding instructional design and priority need index of instructional design for safety awareness learning system*

Perceived Importance of Instructional Design	Current State		Desirable State		t	sig	Need Assessment	
	Mean	SD	Mean	SD			PNI	Ranking
4. Learning system that evaluates and analyzes learner's knowledge level before each topic.	2.73	0.96	3.90	0.92	19.94	0.00	0.43	1
6. Learning system that allows learner to control the topic sequence.	2.81	1.09	3.96	1.02	17.23	0.00	0.41	2
7. Learning system that allows learner to select any activity that achieves same outcome.	2.86	1.05	3.96	0.98	16.55	0.00	0.39	3
5. Learning system that adapts difficulty according to learner's need.	2.90	1.03	4.00	0.93	16.92	0.00	0.38	4
10. Learning system that demonstrates necessary skills before practice.	2.94	1.02	4.02	0.97	19.40	0.00	0.37	5
12. Learning system that allows learner to practice part-tasks.	2.92	1.01	4.01	0.95	18.66	0.00	0.37	5
19. Learning system that can analyze the solution and guide the learner to solve the problem.	2.95	1.04	4.04	0.93	17.88	0.00	0.37	5
1. Learning system that informs learner of	2.94	0.96	4.00	0.95	17.82	0.00	0.36	8

Perceived Importance of Instructional Design	Current State		Desirable State		t	sig	Need Assessment	
	Mean	SD	Mean	SD			PNI	Ranking
overview and objective of the lesson.								
2. Learning system that informs learner to the importance of the lesson.	2.95	0.90	4.02	0.94	17.20	0.00	0.36	8
11. Learning system that allow learner to practice different sub-skills before practicing the combined skill.	2.91	0.99	3.95	0.99	17.34	0.00	0.36	8
13. Learning system that shows changes in effects when learner manipulate the working conditions.	2.92	0.99	3.97	0.93	17.89	0.00	0.36	8
8. Learning system that suggests the link between theoretical and practical aspects of the lesson.	2.96	1.00	4.00	0.96	17.45	0.00	0.35	12
15. Learning system that has constant open access to supportive information needed for the lesson.	2.99	0.97	4.04	0.96	17.24	0.00	0.35	12
21. Learning system that informs the learning progress.	2.95	1.06	3.98	0.98	16.30	0.00	0.35	12
22. Learning system that guides the learner to reflect about the importance of the problem and guides the learner through hypothesis testing procedure.	2.92	1.01	3.94	1.00	16.28	0.00	0.35	12
23. Learning system that gives feedback about the learner's problem-solving process.	2.94	1.03	3.96	1.00	16.81	0.00	0.35	12
18. Learning system that gives corrective feedback to the learner by informing cause, prevention method, and solution of the mistake made during the lesson.	2.98	1.00	3.99	0.94	17.36	0.00	0.34	17
20. Learning system that is interactive.	2.94	1.09	3.94	0.96	15.76	0.00	0.34	17

Perceived Importance of Instructional Design	Current State		Desirable State		t	sig	Need Assessment	
	Mean	SD	Mean	SD			PNI	Ranking
14. Learning system that presents multiple examples during lesson.	3.00	1.00	4.00	0.96	17.22	0.00	0.33	19
3. Learning system that informs rules and direction of the lesson before learning.	2.94	0.94	3.88	0.96	15.81	0.00	0.32	20
9. Learning system that explains steps or guidelines of the working process before lesson.	3.10	1.02	4.06	0.98	16.88	0.00	0.31	21
16. Learning system that provides high level of supports during the beginning of the lesson and reduces the supports when the learner has mastered the skill.	3.05	0.93	3.99	0.95	16.13	0.00	0.31	21
24. Learning system that allow the learner to restart the lesson at any time.	3.12	1.09	4.10	0.93	16.54	0.00	0.31	21
25. Learning system that enables the learner to conclude the lesson.	3.17	1.10	4.15	1.02	15.60	0.00	0.31	21
17. Learning system that suggests hints, alternatives, or further useful information, during the lesson.	3.08	1.01	4.01	0.99	15.03	0.00	0.30	25
Overall	2.96	0.69	4.00	0.72	24.61	0.00		

* PNI $_{modified}$ = (I – D) / D In this formula (I) refers to Importance (the desirable state), and D refers to Degree of success (the current state). The value of PNI indicates the importance of the gap. The higher the value, the more important.

Discussion

The participants of this research were 355 undergraduate students, consisting of 211 students (59.4%) from Burapha University, 106 students (29.9%) from Srinakharinwirot University, and 38 students (10.7%) from Rajamangala University of Technology Rattanakosin. Being diverse in locations, the three universities could represent the demographic population of gems and jewelry students from universities nationwide, both from metropolitan and provincial areas.

Most of the students, 306 participants (86.2%) to be precise, stated that they own personal computers or laptops. Of the remaining 49 participants who do not own personal computers or laptops, 42 of them (85.7%) had access to

university computers, leaving only 7 individuals (14.3%) who claimed they do not have access to any computer. These figures showed that almost all students have access to computers, either to their own or the university's. Thus, it is safe to conclude that it is applicable to develop and implement a computer-based learning system for safety awareness for undergraduate students majoring in gems and jewelry in Thailand.

Even though during their undergraduate studies, the students have been exposed to a wide range of classes relating to gems and jewelry manufacturing, but the research found that 224 students (63.1%) believed they have not been taught about safety awareness. Only 131 students (36.9%) stated that they had been trained for safety awareness in their studies. However, further investigation among those 131 participants revealed that their average overall safety awareness, despite having been through safety awareness training, was only at medium level (Mean = 2.84, SD = 0.60). Medium level of safety awareness is arguably less than desirable for jewelry workers who holds the responsibility not only in the safety of high value properties, but also in the safety of lives of many workers involved in the manufacturing process. A systematic and well-designed learning system for safety awareness for gems and jewelry students is undeniably much needed.

Conclusion

In summary, the safety and welfare of the jewelry manufacturing workers in Thailand have been underprivileged. The problem has been neglected and remained unsolved for many years (Gemological Institute of Thailand, 2014). Since the major cause of work-related accident has been from the errors of workers themselves (Sole et al., 2013; Sonprom, 2012; Zhao & Lucas, 2014), the appropriate approach for accident prevention is to develop a learning system that promotes safety awareness among the workers, which should be implemented during undergraduate studies to equip the students with safety awareness before they enter the workforce. Initial survey of this research confirms that the students would greatly benefit from a safety awareness learning system because it was found that majority of the students believed they have never been taught about work safety. Further investigation found that for those who had been through work safety training, the students rated themselves having only medium level of safety awareness, which is arguably undesirable.

To design a safety awareness learning system that is appropriate and interesting to the students, instructional design strategies were investigated. Relevant instructional design strategies were abstracted from the frameworks of adaptive instruction, procedural simulation, and 4C/ID. At current state, the

students perceived that those instructional design strategies were being implemented in their studies only at medium level (Mean = 2.96, SD = 0.69), while their desirable state of perceived importance regarding those instructional design was at high level (Mean = 4.00, SD = 0.72). Statically analyzed, all the items of the desirable state of perceived importance regarding instruction design of safety awareness learning system was significantly higher than current state at .05 level.

To find out the priority need in designing the learning system with suitable instructional design, the differences in the value of current and desirable state were calculated and ranked using $PNI_{modified}$ formula, resulting in top five instructional design as followed: 1) Learning system that can evaluate and analyze learner's prior knowledge level before each topic, 2) Learning system that allows learner to control the topic sequence, 3) Learning system that allows learner to select any activity that achieves same outcome, 4) Learning system that adapts the difficulty of lesson according to learner's need, and 5) Learning system that demonstrates necessary skills before practice.

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