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The Effects of Students' Learning Anxiety and Motivation on the Learning Achievement in the Activity Theory Based Gamified Learning Environment

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ABSTRACT
The advancement of mobile game-based learning has encouraged many related studies, which has enabled students to learn more and faster. To enhance the clinical path of cardiac catheterization learning, this paper has developed a mobile 3D-CCGBLS (3D Cardiac Catheterization Game-Based Learning System) with a learning assessment for cardiac catheterization, and which also evaluates the learning effectiveness, based on ARCS (Attention, Relevance, Confidence and Satisfaction) theory. This study implemented a quasi-experimental design, using 102 students with the relevant medical background, divided into three groups. The learning achievements of this study show that the experimental group achieved higher scores than both control groups. The statistical analysis of the learning motivation and learning achievement shows ARCS-R (Relevance) as the most important factor, followed by of ARCS-C (Confidence). The results show that the learning content was relevant to the learner's level, and that it brought more confidence and increased the effectiveness of learning.
Keywords: mobile game-based learning, activity theory, ARCS model, cardiac catheterization

INTRODUCTION

Mobile devices have developed rapidly and have become very popular. This trend facilitates data collection, processing and analysis, and the high interactivity, enabled by beaming, makes collaboration and communication among students functional. Therefore, the mobile is regarded as a rich source of information in real life, from which more and more information can easily be obtained. With interactive exchanges, knowledge from the internet is more immediately accessible than that learned in the classroom. Traditional ways of instruction and one-way knowledge acquisition neither attract nor satisfy the demands of the information society's youth. With the convenience and interactivity of networking, as well as the flexibility of time and location, e-learning has become the current trend in educational development. With the prevalence of the internet, information technology is rapidly being integrated into

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State of the literature

- Based on the activity theory to develop a mobile 3D medical simulation game which helps familiarize the operation of the clinical pathway of cardiac catheterization.
- The situational simulation game allows learners reinforcing the knowledge cognitive scheme.
- The result found that the motivation to actively participate in learning would positively affect learning outcome, which would further influence medical anxiety and can reduce the medical fear.

Contribution of this paper to the literature

- To develop a mobile 3D medical simulation game enhancing learning.
- To understand students' viewpoints, regarding situational game-based learning.
- To ascertain whether enhance cardiac catheterization knowledge can reduce the fear.

industries, and such information systems are enhancing efficiency, saving time, and becoming a primary tool for enterprise management, decision-making, competition and development. In the medical community, several instruments and some equipment have been developed with information technology, and these reduce both time and cost. Further, many people invest in developing medical education software to assist the public in acquainting itself with health care-related information.

No matter how much information technology advances, the abundance of technology in the medical community is developed to correspond with those who already have a medical background. For some segments of the public, it is difficult to understand the utility of advanced technology. Moreover, health care knowledge is often conveyed by doctors or the media. Most people do not actually understand the causality, as they are inadequately informed in the area of health care knowledge, and the media often do not clearly deliver medical educational information. Medical students require practical training to understand an entire operation process. Nevertheless, students who take the relevant courses still are not entirely able to realize the operation process, as they receive only theoretical knowledge from teachers and textbooks. They learn "what to do" without knowing "how to do it." The educational trend in applying mobile-based and high-feedback game-based learning to increase the chance of practice stimulates students' learning interests and enhances their achievements.

From the aspect of education, Dewey (1938) proposed "learning by doing," which promoted the notion that progressive education allowed learners to learn from activities. With situational game-based simulation, the cardiac catheterization experienced by students enhances their learning. Each student presents distinct learning speeds and methods. With traditional ways of instruction, it is difficult for teachers to offer adjustable guidance to a class. In recent years, personalized learning has become one of the focused educational policies, in which the past teacher-centered instruction has been transformed into individually suited student-centered learning. In a learner-centered environment, e-learning could achieve personalized learning, as students could self-monitor and arrange instruction content and schedule according to their individual needs. Likewise, they could repeatedly negotiate the unfamiliar parts with the system feedback in order to increase their learning achievements. Digital game-based learning presents abundant characteristics, appealing to students' learning motivation, including: representation, fun, playfulness, goals, interactivity, outcome feedback, win states, competition/challenge, problem solving, tasks and story (Felix & Johnson, 1993; Prensky, 2001; Fan & Su,2015;Su & Fan,2014;Su & Cheng,2015). Varying game levels could add a sense of playfulness to monotonous classes and a non-overwhelming challenge to the more difficult ones. The knowledge and skill levels needed for the curriculum could be clearly presented in games, and various dialogues and situations could attract students' attention, retain their interest and learning motivation, and promote their learning achievements. Csikszentmihalyi (1989) proposed the components of control, attention, curiosity, and intrinsic interest, with which people totally focused on particular activities, passionately looked for answers, and happily learned when in a flow state so that games were not simply for entertainment.

Although learning and games seem to be at odds with each other, the popularity of online games and the development of e-learning have favorably impacted digital game-based learning systems and are being utilized for personalized learning and to solve some of the problems of traditional instruction methods. Based on the content of cardiac catheterization, the fun, playfulness and interactivity of games have been integrated into the medical curriculum, and students are "learning by doing." The purpose of this study is to improve the unvaried traditional ways of instruction. This study develops a task-based 3D-CCGBLS for students to learn the cardiac catheterization operation process, and a role-play component to enhance their learning achievements.

In sum, this study has four purposes: (1) to remediate some of the problems inherent in traditional instruction methodology and to enhance student learning achievement, with the aid of a situational, mobile, game-based learning system; (2) to understand students' viewpoints, regarding situational, mobile, game-based learning; (3) to ascertain whether cardiac catheterization knowledge can reduce the fear of cardiac catheterization; (4) to build the optimal learning achievements model for learning motivation by multiple regression.

RELATED WORKS

Clinical path of cardiac catheterization

Clinical path is regarded as a major tool in managing medical quality and efficiency, and it is the main methodology used by medical experts attending patients. The introduction of clinical path to hospitals aims to present the economic effects, guarantee medical quality, and enhance patient and medical staff satisfaction. Hospitals, therefore, could ensure the quality of care and the costs through the promotion of case management and clinical path.

Many authors have identified several advantages of clinical pathways for hospitals and patients (Archer et al., 1997; Bailey, Weingarten, Lewis, & Mohsenifar, 1998; Cardozo et al., 1998; Chin et al., 2002; Coffey et al., 1992; Dooley & White, 2003; Goldberg, Chan, Haley, Harmata- Booth, & Bass, 1998; Johnson et al., 2000; Kitchiner & Bundred, 1996; Pestian et al.,1998; Phillips & Crain, 1998; Wazeka et al., 2001; Welsh & Magnusson, 1999). Some of the advantages of clinical pathways are, as follows: (1) decreased length of hospital stay: according to Lagoe and Lagoe (1997) a reduced length of stay LOS (Length of Stay) is associated with the use of clinical pathways. Decreased lengths of stay are perhaps the most significant advantage of clinical pathways, and this in itself is a self-evident positive outcome for both the patient and the health care agency; (2) cost containment: cost containment continues to be a crucial issue for all health care organizations. Greenwood's (1996) sustainable claim, that departure from the critical pathway increases the cost of patient care, is an influential factor in the adoption of pathways as a care model. It could further be argued that organizations primarily implement clinical pathways as a cost managing method; (3) consistency and coordination of care: according to Colucciello & Mangles (1997) not only are clinical pathways an essential step forward in resource and time efficiency, they also provide improved collaboration and coordination of care; (4) team-building: Luc (2000) argues that a clinic pathway helps health care teams achieve higher levels of success. Additionally, it can be competently argued that any improvement in team relations results in a more seamless and satisfactory realization of mutual goals; and (5) measurability: Smith and Gow (1999) point out that a major benefit of pathways is that they provide a means of measuring care delivered, thus, directly linking care to quality and using clinical pathways as a management tool.

Cardiac catheterization is an examination in which a long, flexible catheter, opaque to X-rays, is inserted from the femoral artery of a lower limb or radial artery of an upper limb to the heart. Clinical path refers to a group of experts formulating a standard treatment for a specific patient and in accordance with a specific operation. In a specific diagnosis or process, the optimal medical sequence is defined and the key interference is scheduled (Coffey et al., 1992).

Medical anxiety

Anxiety has been defined as a feeling of fear, tension or panic, or an expectancy that something unpleasant is going to happen (Frederickson, 1989; Medalie & Goldbourt, 1976). Patients scheduled for cardiac catheterization are often anxious and frightened. High levels of anxiety may result in a more difficult and painful procedure. Past research has reported mixed results with anxiety reduction techniques in other procedure settings, such as educational, cognitive-behavioral, coping and relaxation, combinations of techniques, and music (Martha et al., 2006; Wynne et al., 2004; Renée et al., 2010; Heng-Hsin,2009). Stereotypical cardiovascular symptoms of anxiety are cardiac irritability, increased basal metabolic rate, bronchoconstriction, and increased blood pressure caused by peripheral arterial vasoconstriction, all of which can raise the level of risk in a cardiac catheterization procedure (Moos& Engel, 1962).

Patients about to undergo a diagnostic and/or interventional vascular angiography procedure are often anxious and frightened, and their anxiety may influence their physiologic responses, such as respiratory rate, heart rate, blood pressure, myocardial oxygen consumption, and plasma concentrations of epinephrine and norepinephrine (Bassam etl, 1980; Burch, 1973; Turton etl, 1977).

There is considerable evidence indicating that a patient's functional and psychological status can deteriorate during the wait for a cardiac surgery (Toe et al., 1999; Arthur et al., 2000; Bengston et al., 1966; Beckerman et al., 1995, 2000; Jonsdottir & Baldursdottir, 1998; Mulgan, 1990). Beckerman (Beckerman et al., 1995) noted that "The waiting period for cardiac catheterization was characterized by increased anxiety, with the mind in a state of constant thought and flux" due to fear of the unknown. Therefore, a better understanding of anxiety and cardiac catheterization health-related issues is needed to guide clinical practice.

Mobile game-based learning

Several researchers have indicated the benefits of using mobile devices for learning and teaching (Csete, Wong, & Vogel, 2004; Vahey, Tatar, & Roschelle, 2007). Mobile devices allow learning anytime and anywhere (Salinas & Sánchez, 2006). Other researchers have demonstrated successful experiments supporting knowledge production and transmission among learners and educators through mobile devices in the learning activities of various courses, such as natural science (Huang et al., 2010a), social science (Chiou et al., 2010), and language (Ogata et al., 2009; Sandberg et al., 2011). Mobile devices can also help students make online-assisted decisions (Syvanen, Beale, Sharples, Ahonen, & Lonsdale, 2005). Moreover, the proliferation of mobile devices has so rapidly expanded because they can easily access, process and analyze data by beaming, facilitating collaboration and communication among students and teachers. Learners cannot only access course content and information, but are given opportunities to converse and collaborate with classmates through the use of mobile technologies, thereby meeting higher-level learning needs and helping realize a more creative and learner-centered educational process (Joo & Kim, 2009). For example, Chen et al., (2003) proposed a mobile learning system for scaffolding bird-watching learning activities, which enabled students to take photos of birds with handheld devices and to communicate with teachers and other students in an outdoor wireless environment. Lai et al., (2007) noted the affordances that mobile technologies provided experiential learning by allowing rapid "note taking" through photos, audio and video recording, and by supporting students with an in-field provision of learning materials and prompts to assist in their development of abstract concepts.

Furthermore, recent research findings showed that digital learning resources, alongside real-world learning contexts, improved students' learning motivation (Chen et al., 2003; Huang et al., 2009; Hwang et al., 2010; Zhang et al., 2010) and learning achievement (Hwang et al., 2010; Hwang & Chang, 2011).

Therefore, this study aims to develop a 3D mobile game-based learning system with a cardiac catheterization clinical pathway, which can promote knowledge in, and the skill process of, cardiac catheterization in order to engage the learner and increase motivation.

Activity theory

Activity theory is initiated by a group of Russian psychologists, notably Vygotsky and Leont'ev in in the 1920s and 1930s (Engeström, 1987; Leont'ev, 1978; Leont'ev, 1981a, 1981b). Engestrom (1987, 1993) utilized activity theory to understand how human beings move through the media of tools and cultural background information, and emphasized the interactions among languages, peoples and environments. According to Leont'ev, an activity is initiated by a motive such as a need or drive. An activity is made up of one or more actions the completion of which satisfies the initial motive. An activity and all the component actions (see **Table 2**) are always realized in specific contexts which determine to a large extent the conditions under which the actions can be realized and the initial motive can be satisfied. Carvalho (2015) present a model for serious games analysis and conceptual design, called Activity Theory-based Model of Serious Games (ATMSG) which supports a systematic and detailed representation of educational serious. Daniel (2010) indicated that human behaviors should be analyzed and that the purposes of human activities were divided by results, according to activity theory. The model of activity theory includes six components of human interaction: subject, object, tool, community, rule and division of labor. Activity theory could be the basis of educational game development, which aims at a collaborative learning environment. In such an educational game-based interaction, the learning outcome is predictable (Paraskeva, Mysirlaki & Papagianni, 2010). Activity Theory frameworks and methodologies for serious games analysis and design that provide useful interpretations of the possibilities and limitations offered by serious games (Carvalho et al, 2015). Ilias Karasavvidis (2009) proposed Activity Theory as a conceptual framework for understanding teacher approaches to Information and Communication Technologies. Based on the benefit of Activity Theory, Therefore this paper proposed technology-based innovation using Activity Theory as a serious game design theoretical framework enhancing learning.

ARCS learning motivated model

Keller (1983) proposed an ARCS Motivational Model. Based on the systematic design model to encourage the learning motivation of students, the motivation theory and the relevant theories were integrated. He considered that traditional instructional design was only slightly concerned with learning motivation, and that the materials developed from any instructional designs could not enhance knowledge acquisition when the learner's interests or attention were not induced.

To accurately measure the change in learner motivation, Karoulis and Demetriadis (2005) suggested that the ARCS model (Keller, 1987) could be the standard of the learning motivation increased by the game. Keller (1983) regarded a learner's efforts as dependent on individual factors of value and anticipation; both were the bases of individual motivation, which was the functional composition of value and anticipation, actively moving towards the goal, as individuals anticipated satisfaction and success. Keller (1987) stressed the diagnostic and prescriptive functions of ARCS with which instructors could conduct strategies to compensate learners' insufficient motivation. Motivation is regarded as the essential element of successful learning, as motivated learners tend to learn constantly (Prensky, 2003). The ARCS motivation model aims to assist in curriculum design and stimulate learning motivation (Keller, 1983). In order to measure the change in learning motivation, Karoulis and Demetriadis (2005) argued that the ARCS model (Keller, 1987) could be the criterion and reference to judge the enhancement of learning motivation through a game.

METHOD

This chapter contains three sections, including the proposed research flow, namely, Research framework, Operationalization of variables, and Experimental design.

Research framework

In order to explore learners' learning motivation and learning effectiveness with the developed 3D-CCGBLS, the related information technology and educational theories have been applied. A learning motivation scale and a medical anxiety scale were, therefore, applied to measure learners' learning motivation, learning effectiveness, and medical anxiety with a 3D cardiac catheterization game-based system. Summarily, based upon the relevant research as discussed in Related Works, **Figure 1** shows the hypotheses to be examined. From relevant studies (Hodgins et al., 2002), we know that gender affects learning motivation and anxiety. Therefore, this research leads to two hypotheses:

H1: Demographic variables show positive effects on a 3D cardiac catheterization game-based learner's learning motivation.

H2: Demographic variables show positive effects on a 3D cardiac catheterization game-based learner's medical anxiety.

Previous studies (Chen et al., 2010; Liu & Chu, 2008; Huang et al., 2010) found that learning strategies had a positive effect on learning motivation and learning achievement. Therefore, this research proposes two hypotheses:

H3: Different learning strategies reveal positive effects on a 3D cardiac catheterization game-based learner's learning motivation.

H4: Different learning strategies reveal positive effects on a 3D cardiac catheterization game-based learner's learning achievement.

The relevant research (Keller & Suzuki, 2004; Snezana et al., 2012; Ulrike, 2012; Michelle, 2012) shows that motivation will have a positive influence on achievement and anxiety. Based on this research, this study proffers two hypotheses:

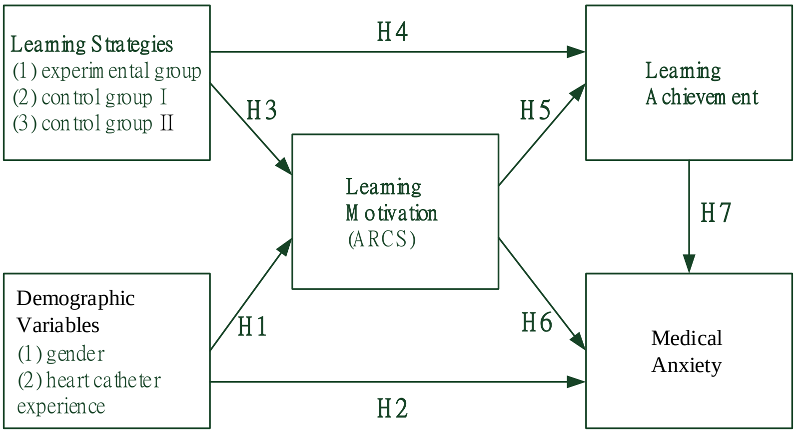

Figure 1. Research framework

H5: Learning motivation displays positive effects on a 3D cardiac catheterization game-based learner's learning achievement.

H6: Learning motivation displays positive effects on 3D cardiac catheterization game-based learner's medical anxiety.

Based on the relevant research (Azizreza, 2011; Hwang & Chang, 2011; Jelte M.,et al., 2010), learning achievement will affect anxiety, leading to hypothesis seven:

H7: Learning achievement presents positive effects on a 3D cardiac catheterization game-based learner's medical anxiety.

Operationalization of variables

For ease in understanding, this section summarizes the operationalization of constructs in Table 1. Six demographic variables are included: gender (male and female), subject interest (student's interest in a cardiac catheterization clinical pathway), prior family experience (prior experience with smartphone use), working off-campus (amount of time working/week off-campus), game use frequency (times played/week), and play time (total hours played/week). For gender, F denotes females, and M, males. For interest, N denotes students who are not interested in a cardiac catheterization clinical pathway, and Y denotes the students who are. For prior experience, N denotes the students who had absolutely no experience with smartphones, and W denotes the students who had used a smartphone application.

Table 1. Operational definitions

Construct	Operational definitions	Source
Demographic variable	Demographic variable profiles students according to gender, subject interest, prior experience, working off-campus, game use frequency, play time.	Hodgins et al., 2002, this research
Learning strategy	Experimental group: Using 3D-CCGBLS to understand the process of a cardiac catheterization operation. Control group 1: Uses e-learning to understand the process of a cardiac catheterization operation. Control group 2: Uses a traditional teaching approach to understand the process of a cardiac catheterization operation.	Chen et al., 2010; Chu et al., 2008; Huang et al., 2010
ARCS learning motivation	The ARCS model identifies four essential strategies for motivation instruction: attention, relevance, confidence and satisfaction.	Keller & Suzuki, 2004
Medical anxiety	Medical anxiety is commonly used to measure the anxiety state of a cardiac catheterization patient. It is also used to diagnose anxiety and to distinguish it from depressive syndromes.	Spielberger et al.,1983; Snaith et al.,1982; Hamilton, 1959
Learning achievement	The degree to which a specific learner activity imposes a germane and extraneous load onto working memory.	Hwang & Chang, 2011

(1) Research variables

1. Instruction strategy

Regarding the instruction methods, the experimental groups received a 3D cardiac catheterization mobile game-based learning system. While control group 1 received online, material-assisted instruction, and control group 2 received traditional instruction. With such distinct instructional strategies, the learning effectiveness with a 3D cardiac catheterization clinical pathway was observed.

2. Basic demographic variables included gender, experience in internet surfing, experience with games, and family experiences in cardiac catheterization.

3. Achievement contained three groups: high, medium and low achievement. The Learning Achievement Test refers to an achievement test of students who received a 3D-CCGBLS after experimental instruction. The index indicates that the higher the score, the higher the learning achievement.

4. ARCS Learning Motivation Scale was revised by the experts' opinions, collected by the instructional experiment, and demonstrated that the higher the score received, the stronger the learning motivation shown by the students. In order to test the differences between the experimental and the control groups, the pretests were regarded as a covariance, the post-tests were the dependent variables, and the group's factors were fixed for one-way analysis of covariance.

5. The Medical Anxiety Scale, derived from the Hamilton Anxiety Scale (HAS), Beck Depression Inventory (BDI) and State-Trait Anxiety Inventory (STAI), has been widely used in the fields of medicine and education (Spielberger el al.,1983; Snaith & Baugh, et al.,1982; Hamilton,1959; Arthur et al., 2000). Therefore, the medical anxiety scale was referenced from the Hamilton Anxiety Scale (HAS), Beck Depression Inventory (BDI) and State-Trait Anxiety Inventory (STAI) and used to measure the traits and anxiety state of cardiac catheterization. It can be used in clinical settings to diagnose anxiety and to distinguish it from depressive syndromes. There are 6 items used to assess the state of cardiac catheterization medical anxiety, as shown in **Table 4**. The results were measured by the 5-point Likert scale. The questionnaire was designed to find out about the learner's medical anxiety, regarding cardiac catheterization.

Experimental design

Based on convenience, two classes from the Department of Nursing at southern Taiwan University were sampled as research subjects. The pretest result of the knowledge of a cardiac catheterization clinical pathway in the two classes was tested to confirm learning capability homogeneity.

With random sampling, two classes with 102 students were apportioned into three groups. The 34 students in experimental group proceeded to 3D cardiac catheterization mobile game-based learning. The next 34 students, control group 1, preceded to a web-based e-learning. The last group of 34 students, control group 2, preceded along the path of traditional text instruction. Based on the control variable of our quasi-experimental design, the three groups were taught by the same teacher.

Experimental processing stage

This quasi-experimental design incorporates four steps, as listed below. First, discuss the course content of the experimental instruction with the student. Second, select the research samples, based on the quasi-experimental design, from two classes of the Department of Nursing in a southern Taiwan university, and randomly distribute them into an experimental group, for 3D cardiac catheterization game-based instruction, a control group 1, for web-based e-learning instruction, and a control group 2, for traditional text instruction. Third, discuss the experimental instruction process and content with the advisor. Fourth, have the experimental group get used to the software interface and the relative functions and environment before given the experimental instruction.

There are three stages to the experimental process, as shown in **Figure 2**:

(1). Pretest stage
So as to ensure the homogeneity, the three groups were pretested on a cardiac catheterization clinical pathway for 50 minutes before the experiment. The pretest was used as a reference for the partitioned group.

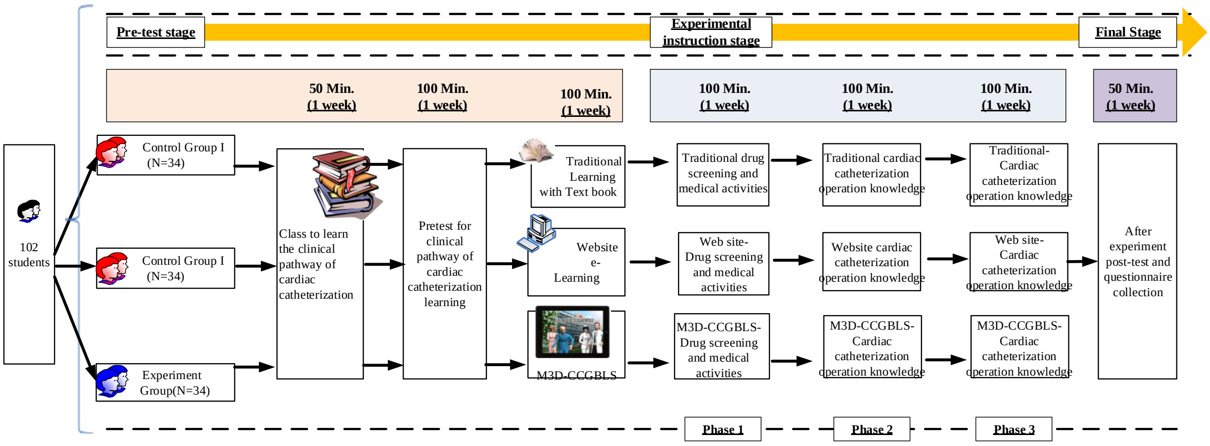

Figure 2. Experimental design process

(2). Experimental instruction stage

Experimental control groups 1 and 2 were taught by the same teacher for 9 sessions in three weeks. The learning content was the clinical pathway of cardiac catheterization, which was divided into knowledge before, in the middle, and after the operation of the clinical pathway of cardiac catheterization. The instructional activities at each stage were assisted by computer games and discussions. Both formative evaluations and open questionnaires were implemented after the instructional activities, so as to analyze students' learning effectiveness at the three stages. With the post-test results, the study conducted a statistics test in learning motivation and learning effectiveness of students.

(3). Final stage

The experimental group and the two control groups received the clinical pathway of cardiac catheterization test in order to understand the differences of learning motivation, learning effectiveness and medical anxiety among them. The data were analyzed and the effectiveness and learning motivation were compared by statistical analysis. The collected quantitative data were analyzed with SPSS, so as to understand the differences of research variables among the experimental group and the two control groups after the instruction.

SYSTEM DESIGN AND IMPLEMENTATION

In accordance with the system design and implementation, a three-step section was formulated, teaching content mapping to learning system was designed into the learning system as an instruction component. After that, an architectural system was built to service the content flow. Finally, the game interface was designed and developed for game users.

Teaching content mapping to learning system

Aiming at the instructional activity design of cardiac catheterization, the contents of the clinical pathway of cardiac catheterization are first described. The combination of activity

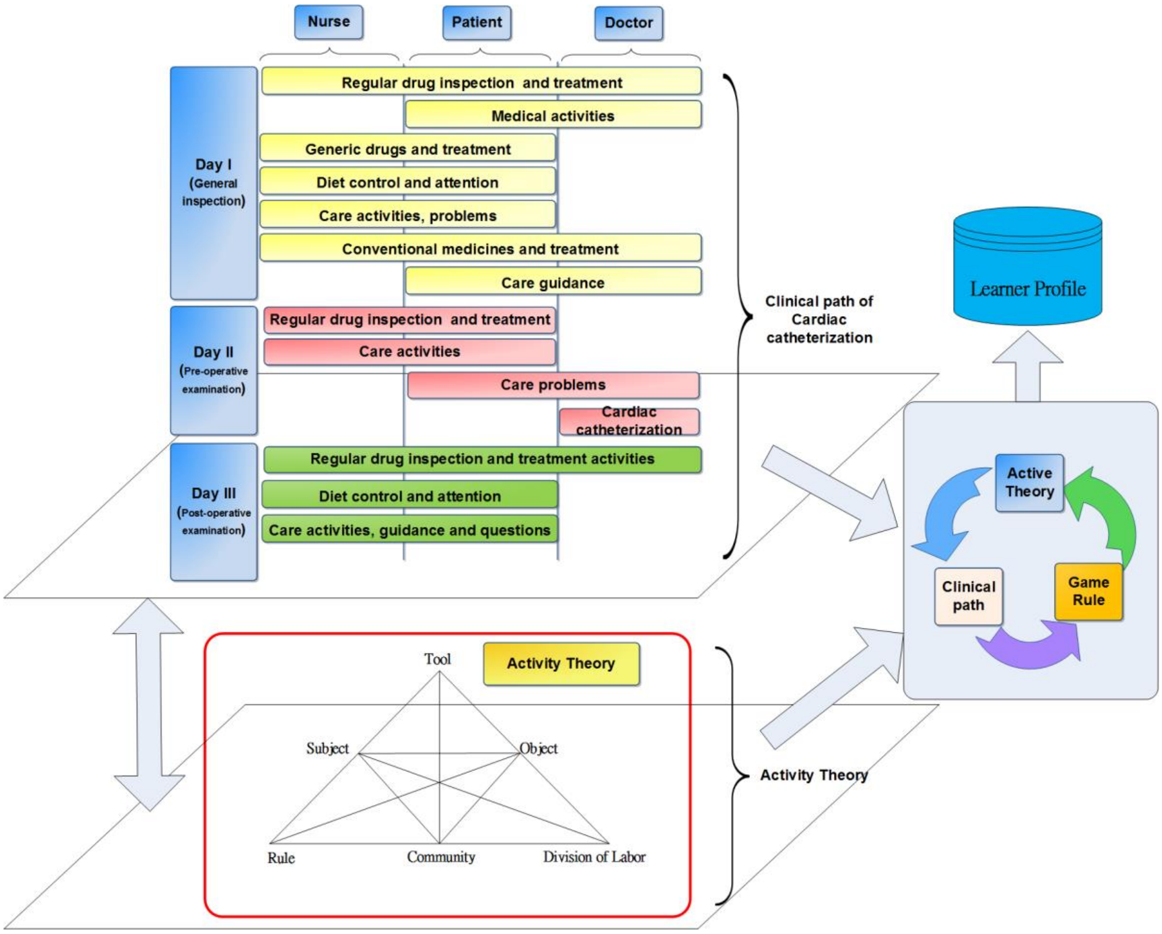

Figure 3. Teaching content mapping to system

theory and the cardiac catheterization clinical pathway is further demonstrated. Finally, the indicators for the game-based clinical pathway of cardiac catheterization learning are designed and the learning activities in the learning process are collected for further evaluation of their learning effectiveness.

This mobile, 3D cardiac catheterization, game-based learning content was designed to contain two activities, as **Figure 3**:

(1). The clinical pathway of cardiac catheterization: the three-day activities composed of patients, nurses and doctors allow patients to understand the procedure of a routine examination, medical activities, general drug and therapy, diet control and attention, nursing activities, problems, guidance, and the operational procedures of the units involved in each activity.

(2). Activity theory: Being the interactive basis of instruction, the interaction contains tools, subjects, rule, community, division of labor and objects, which could assist the contents'

Table 2. Activity theory-based learning content mapping to game design

Activity Theory	Clinical pathway of cardiac catheterization		Game level design	Learning indicators
1.Tool 2.Subject 3.Rule 4.Community 5.Division of Labor 6.Object	Day1	Routine examination Medical activities General drug and therapy Diet control and attention Nursing activities, problems and guidance	1.Routine examination level 2. Routine drug and therapy level 3. Test level	1. Examination cognition of the cardiac catheterization operation 2. Drug therapy before the cardiac catheterization operation
	Day2	Routine drug and therapy Diet control and attention Nursing activities, problems and attention Operation procedure steps	1.Simulation operation of cardiac catheterization game level 2.Test level	Cardiac catheterization operation training (1. stability; 2. response; 3. control; and 4. integration of procedure and knowledge)
	Day3	Routine examination General drug and therapy Diet control and attention Nursing activities, problems and guidance	1. Routine examination after the operation 2. Nursing guidance after the operation 3. Test level	1. Examination knowledge after the operation 2. Daily health care after the operation 3. Basic nursing and health care

being more active in achieving the instructional effects. Finally, the learning indicators are completed by integrating the game-based design, the knowledge of the clinical pathway of cardiac catheterization, and the activity theory, shown as **Table 2**.

The player's learning achievement indicators (see **Table 2**) are collected and stored for future evaluation of the learning effectiveness. Game levels include: (1) routine examination level, aiming at the examination cognition of a cardiac catheterization operation; (2) routine drug and therapy level, focusing on the drug therapy before a cardiac catheterization operation; (3) operation level, simulating a real cardiac catheterization operation; (4) routine examination after operation, emphasizing post-operative examination knowledge; and (5) post-operative nursing level, aiming at the daily health care after the operation.

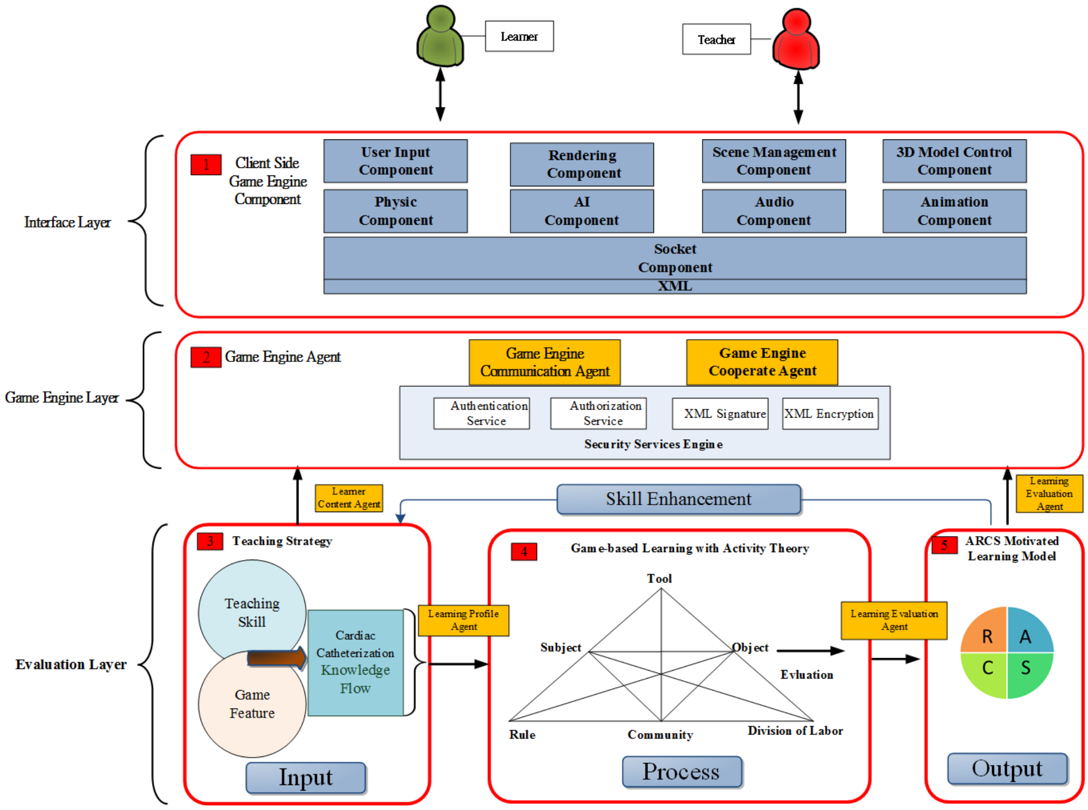

Figure 4. Mobile 3D-CCGBLS architecture

System architecture

The mobile 3D-CCGBLS architecture contains a three-layer system framework with five processes. To enhance the utility of the system, the five processes (modules) were integrated into a friendly 3D-interfaced, interactive, cardiac catheterization, game-based, instructional system.

For ease in the understanding the system operation. The proposed system architecture contains three layers with five processes, numbered in red, as **Figure 4**. The detailed five processes are introduced, as follows:

The Interface Layer: the user-interacted layer monitors and controls users' interactive games and manages the game process.

The Game Engine Agent Layer: the game engine agent layer manages and controls engine components.

The Evaluation Layer: the game evaluation layer classifies the players' levels, so as to more suitably distribute them. Furthermore, the activity theory and the cardiac catheterization game-based learning contents combine to form an ARCS learning motivation model.

Process 1: Client-end game engine component: Users interact with the client side game engine component in the procedure, including user input component, rendering component, scenes management component, 3D model control component, physic component, NPC-non player character AI component, audio component, animation component, and socket component. For cross-platform communication, XML (Extend Markup Language) is applied for exchanges among platforms.

Process 2: Game engine Agent: Game engine agents contain a game engine communication agent for communicating with other agents, and a game engine cooperative agent for game components and cooperating with other agents in asking for game-based learning contents through the game content agent in the security service engine.

Process 3: Teaching strategy: Teaching skill, game feature and cardiac catheterization knowledge flow are integrated as a teaching strategy, which is an input part of the evaluation layer.

Process 4: Activity theory with ARCS learning motivation model: With the integration of the cardiac catheterization game-based learning content, the elements of subject, object, community, tool, rule and the division of labor, in interactive theory, allow users to complete the game-based learning interaction through game-based interactive topics: clear learning objectives, group collaboration within the community, assistance of game-based learning contents, and role-play. Moreover, each activity could attract users' attention through intrinsic (ARCS) learning motivation, so as to enhance the focus and curiosity.

Process 5: ARCS learning motivation model: In this case, the relevance between the user's contents and learner's would be enhanced, the learning motivation of the users would be increased, confidence would be generated after completing a learning task, and the satisfaction in the process or game rewards would achieve learning satisfaction.

System interface design

According to the system plan mentioned, this study develops a 3D-CCGBLS game which functions as follows:

(1) The game situation: the construction of the game, besides the design of the game user interface, also includes a role play design. The 3D-CCGBLS situation is set in a cloud-based service in which the number of clients and the complication of the equipment increase. The 3D-CCGBLS is implemented with a cardiac catheterization clinical path. Players can answer cardiac catheterization questions in a clinical path, thereby, increasing their efficiency. (2) The interface design: the game, which this study develops, takes into consideration the situational background, environment and age of the player, in order to increase the authenticity of the game. Further, it uses a hospital model scene, the doctor and nurse, as people, and the 3Ds Max to complete the actual interface, i.e., the interaction between player and system.

Figure 5-1. Game level menu

Figure 5-2. Situational of the examination room

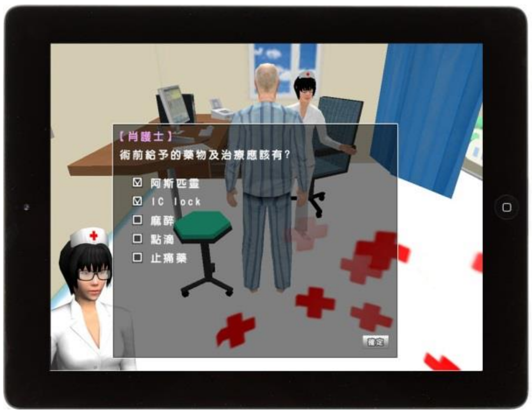

Figure 5-3. Patient's clinic visit

Figure 5-4. Cardiac catheterization simulation Figure in game play

Figure 5-5. Cardiac catheterization evaluation test in game play

Figure 5-6. The result of the cardiac catheterization evaluation test in game play

Learners understand the operation procedure through game-based simulation of a clinical path, and are evaluated according to risk management, procedural knowledge and acquaintance with the qualifications to continue to the next level.

Table 3. Demographic descriptive data

Basic Data		N	%
Sex	Female	48	47.1
	Male	54	52.9
Cardiac catheterization interest	No interest	44	44.1
	Interest	58	55.9
Game experience	No interest	39	38.2
	Interest	63	61.8
Extra-curricular learning	In 5(Hs)	51	50.0
	6-20(Hs)	36	35.3
	Above 20 (Hs)	15	14.7
Course learning	In 5(Hs)	33	32.4
	6-20 (Hs)	20	20.6
	Above 20 (Hs)	49	47.1
In e-learning	In 2 (Hs)	36	35.3
	3-6 (Hs)	36	35.3
	Above 6(Hs)	30	29.4
Family with Cardiac catheterization experience	No	66	64.7
	Yes	36	35.3

With the game-based simulation of a clinical path, this system is expected to achieve three objectives: (1) the simulation of various operations, allowing players to become familiar with the operation processes; (2) the operation simulation, allowing players to understand the complications of the operation processes; and (3) the health care information, allowing the player to acquire knowledge.

The game provides four different game situation level choices. **Figure 5-1** allows the selection of a game situation for the game task. **Figure 5-2** shows a patient checking in for the clinical path of a cardiac catheterization. **Figure 5-3** shows a doctor visiting and talking to a patient. In the Cardiac Catheterization game, this study uses a first person view control of the game, which shows a situational view of cardiac catheterization training. The player must solve all the problems in the game in order to advance. In this task, multiple choice questions are designed by the game's meeting record. Besides solving all the game's problems, **Figure 5-4** shows that the player must find a way out in order to increase his interest and keep his attention on game-based learning. In this task, the player must distinguish the emergencies which might occur in the 3D-CCGBLS. If the answer is incorrect, the health points will be decreased by one, the question will reappear and the countdown will be reset, in order to give the player the chance to correct the mistake.

To increase the challenge of the game, the player must answer in limited time. At the end of the learning phase, the player takes a learning evaluation, shown in **Figure 5-5~5-6**. The learner's learning data is then collected into the learner's portfolio by a mobile intelligent agent and, finally, the learner gets a score, which is provided to the teacher for reference.

Table 4. ARCS and Anxiety questionnaire item

Dimension	Item	Question	Cronbach α	
ARCS-A	1	The learning material themes draw my attention.	0.84	0.89
	2	The manner in which the learning materials are presented helps me focus my attention.	0.91	
	3	I can concentrate on the learning activities.	0.92	
	4	The learning activities can arouse my curiosity.	0.88	
	5	After participating in the learning activities, my cardiac catheterization clinical pathway learning experience was more interesting.	0.90	
ARCS-R	1	I can link the content of this course to the knowledge with which I am already familiar.	0.84	0.86
	2	The content of this course is linked to my daily experiences.	0.88	
	3	The content of this course is valuable and worth learning.	0.83	
	4	The cardiac catheterization clinical pathway learning activity in this course has been very helpful to me.	0.89	
	5	Participating in the learning activities helped me prepare for course exams.	0.85	
	6	I was motivated to know more about the cardiac catheterization clinical pathway after participating in the learning activity.	0.87	
ARCS-C	1	The progressive method of the learning activities meets my expectations.	0.85	0.87
	2	I can control my progress in the learning activity.	0.89	
	3	I am confident that I can accomplish all the activities.	0.84	
	4	I am confident that I can apply what I learn from this course to my daily life.	0.90	
	5	After participating in learning activity, I believe I know enough about the cardiac catheterization clinical pathway to perform well on the final exam.	0.87	
ARCS-S	1	I enjoy the cardiac catheterization clinical pathway learning activity.	0.93	0.91
	2	I am satisfied with my learning achievement in the cardiac catheterization clinical pathway learning activity.	0.92	
	3	I would like to continue using mobile learning applications in the future.	0.98	
	4	I would like to use mobile learning applications in other courses.	0.90	
	5	I prefer game-based learning courses to courses offered in classroom settings.	0.91	
Medical Anxiety	1	I feel nervous about cardiac catheterization.	0.91	0.92
	2	I feel stress about cardiac catheterization.	0.91	
	3	I am fearful about cardiac catheterization.	0.93	
	4	I feel anxious about cardiac catheterization.	0.92	
	5	I am concerned about cardiac catheterization.	0.90	
	6	I feel restless about cardiac catheterization.	0.91	

RESULTS

From the analysis of the ARCS learning motivation scale, this study aimed to discuss the applications of various instruction methods to the learning effectiveness evaluation of 3D medical game-based learning and the effects on empirical research. In regard to the research design, the clinical pathway of a cardiac catheterization learning process was followed.

Table 5. Statistical descriptions of learning motivation and learning achievement with different learning strategies

Variable name	Learning strategies	N	Avg	SD
Learning motivation	A	34	4.0882	0.885
	B	34	3.8118	1.051
	C	34	3.1882	1.325
Learning achievement	A	34	82.94	10.009
	B	34	73.24	8.518
	C	34	72.20	8.128

Descriptive statistical

Of the total sample of 102 students, 52.9% are male, 47.1% female. 55.9% are interested in learning about cardiac catheterization, and 61.8% have game-playing experience. 47.1% of the students spent more than 20 hours per week on their courses. Of special note, 35.3% have had a familial cardiac catheterization experience (see **Table 3**).

Reliability and validation

According to Carmines et al., (1978), a reliability coefficient >0.90 shows a favorable reliability of the test or scale, >0.70 shows the minimum acceptable reliability, and <0.60 shows that the research tool should be revised. Cronbach's alpha value for internal consistency reliability of the post-test was .91, indicating that the tests used in this study were solidly reliable. Additionally, a perception questionnaire from Keller's ARCS model of motivation (Keller, 1987; Keller & Suzuki, 2004) is used. Cronbach's α for each sub-scale was 0.89, 0.86, 0.87, 0.91 and 0.92 (as **Table 4**), respectively. According to the results, the KMO value was 0.88, indicating excellent correlations among these variables.

Data analysis of learning strategies

Based on a one-way analysis of variance, **Table 5** shows different learning strategies could notably affect the awareness of learning motivation, F=22.449, p=.000<.001, reaching a significance of .05. Posteriori comparisons indicate that the experimental group reached a higher degree of learning motivation (M=4.088) than control group 1 (M=3.8118) and control group 2 (M=3.1882), while control group 1 and 2 did not exhibit a significant difference between them. With a correlation index of .494, the learning strategies could explain the 49.4% of the total variance in the learning motivation by the high correlation presented between them. It has been inferred that the statistical power=1.000 shows a statistical correctness up to 100.0%. Meanwhile, **Table 6** shows that students with different learning strategies demonstrated remarkable differences in learning achievement, F=21.33, p=.000<.001, reaching a significance of .05. From the posteriori comparisons, the learning achievement (M=82.94) of the experimental group was significantly higher than that of control group 1 (M=73.24) and control group 2 (M=72.20). According to the .412 correlation index, the learning strategies could explain 41.2% of the total variance of the learning achievement by the high correlation

Table 6. One-way analysis of variance of learning motivation and learning achievement with different learning strategies

Variable name		(SS)	(df)	(MS)	F Value	Scheffe Compare
Learning motivation (H3)	Between	1778.80	2	889.40	22.449***	A>B
	Group	1664.00	99	39.61		A>C
	Sum	3442.80	101			B=C
Learning achievement (H4)	Between	68.13	2	34.06	21.33***	A>B
	Group	2781.86	99	66.23		A>C
	Sum	2850.00	101			B=C

n.s. no Significant p>.05 * P≦0.05 ** P≦0.01 *** P≦0.001 A : Experiment Group、B : Control Group 1、C : Control Group 2 ω^2: Power

Table 7. Statistical descriptions of learning motivation in learning achievement and medical anxiety

Variable name	Learning motivation	N	Avg	SD
Learning achievement	A	34	4.6545	.29787
	B	34	4.0353	.43148
	C	34	3.7667	.54283
Medical anxiety	A	34	4.1818	.62900
	B	34	3.7176	.52468
	C	34	3.4000	.33466

appearing between them. The statistical power=0.89 presents a statistical correctness up to 89.0%. Therefore, hypotheses H3 and H4 are significant (as **Table 6**).

Data analysis of learning motivation

From the above one-way analysis of variance, **Table 7** shows that learning motivation reflects significant differences on learning achievements, where F=29.23 and p=.000<.001 reach a significance of .05. By posteriori comparison, high-score students appear to have a higher learning motivation (M=4.6545) than the medium-score students (M=4.0353), who show a remarkable difference with the low-score students (M=3.7667). The correlation .522 reveals that the learning motivation could explain 52.2% of the total variance of the learning achievements by the high correlation appearing between the two. As a result, the statistical power 0.95 shows an inference correctness up to 95.0%.

Students with a different learning motivation present notable differences in medical anxiety. From the analysis of variance, F=21.69 (p<.05) achieves a significance of .05, indicating that students with acute learning motivation show significant differences in medical anxiety. Meanwhile, **Table 8** shows that students with a high level of motivation (M=4.18) show lower levels of anxiety than medium-level motivation students (M=3.71) and lower-level motivation students, who show a remarkable difference with (M=3.4).

Table 8. The ANOVA of learning motivation in learning achievement and medical anxiety

Variable name		(SS)	(df)	(MS)	F Value	Scheffe Compare
Learning achievements (H5)	Between	6.970	2	3.485	29.23***	A>B
	Group	3.697	99	.119		A>C
	Sum	10.667	101			B=C
Medical anxiety (H6)	Between	1.120	2	881.40	21.69***	C>B>A
	Group	10.475	99			
	Sum	11.595	101			

n.s. no Significant p>.05 * P≦0.05 ** P≦0.01 *** P≦0.001 A : Experiment Group、B : Control Group1、C : Control Group2 ω^2: Power

Table 9. Statistical descriptions of medical anxiety in learning achievement and demographic variables

Variable name	Group	N	Avg	SD
Learning achievement	A	34	4.65	.29787
	B	34	4.03	.43148
	C	34	3.76	.54283
Demographic variable (Sex)	Male	48	3.19	.403
	Female	54	4.00	.970
Demographic variable (Experience)	No	66	4.50	.41138
	Yes	36	3.14	.51253

Data analysis of medical anxiety

Table 10 shows that the learning achievements vary, remarkably, from the medical anxieties, where F=25.47 and p=.000<.001 reach a .05 significance. By posteriori comparisons, the lower-score students show a higher medical anxiety (M=4.65) than the medium-score students (M=4.03) and the higher-score students (M=3.76) (as **Table 9**). The correlation appears to be .69, which allows the learning achievements to explain 69% of the total variance of the medical anxiety by the high correlations appearing between them. The statistical power 0.98 shows the inference correctness up to 98.0%.

In regard to demographic variables, students with cardiac catheterization experiences demonstrate notable differences in medical anxiety, wherein F=21.33 and p=.000<.001 achieve a .05 significance. By posteriori comparison, a student's family with experience exhibits a lower medical anxiety (M=4.5) than families with no experience (M=3.14).

Learning effectiveness prediction analysis

In this section we will present the ARCS data for learning motivation and learning effectiveness with a correlation analysis and a regression analysis.

Table 10. The ANOVA of medical anxiety in demographic and learning achievement

Variable name		(SS)	(df)	(MS)	F Value	Scheffe Compare
Learning achievement (H7)	Between	14.939	2	7.470	25.47***	B>C>A
	Group	9.090	99	.293		
	Sum	24.029	101			
Demographic variable sex (H2-1)	Between	68.133	2	34.067	1.33	
	Group	2781.867	99	66.235		
	Sum	2850.000	101			
Demographic variable experience (H2-2)	Between	68.133	2	34.067	21.33***	N>Y
	Group	2781.867	99	66.235		
	Sum	2850.000	101			

n.s. no Significant p>.05 * P≦0.05 ** P≦0.01 *** P≦0.001 A : Experiment Group、B Control Group1、C : Control Group2 ω^2: Power、N: No Experience、Y: Experience

Correlation analysis of ARCS learning motivation and learning effectiveness

From the basic ARCS data for learning motivation, the learning satisfaction with learning motivation appeared the highest, at 82%, and the system utility also received 86% satisfaction, as shown in **Figure 6**. In the relative matrix among learning motivation, ARCS-A, ARCS-R, ARCS-C, ARCS-S and learning effectiveness, the correlations of all variables achieved significance. The prediction of the correlation among ARCS-R, ARCS-C and learning effectiveness was high, with the correlation coefficient higher than 0.6～0.8. ARCS-C and ARCS-S revealed the lowest correlations. A total of 21 questionnaires resulted in an effective sample of 102 (efficiency= 95%). Cronbach's alpha values of the four items of this study questionnaire are all higher than .80, and the entire questionnaire is α=.95, indicating that the questionnaire is reliable.

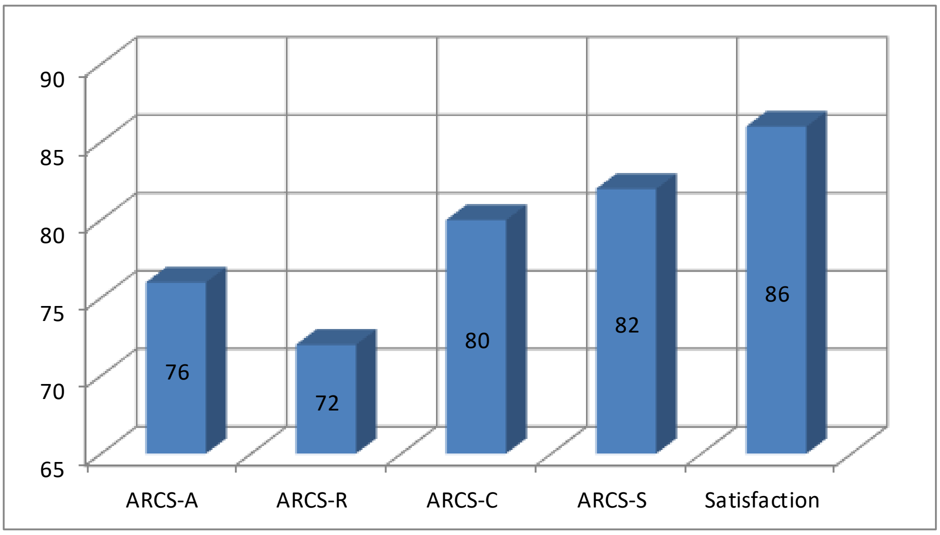

Figure 6. ARCS Average Score

Table 11. Correlation table of ARCS and LA

		ARCS-A	ARCS-R	ARCS-C	ARCS-S	LA
ARCS-A	Pearson Correlation	1				
ARCS-R	Pearson Correlation	.372*	1			
ARCS-C	Pearson Correlation	.291	.794**	1		
ARCS-S	Pearson Correlation	.411*	.380*	.520**	1	
LA	Pearson Correlation	.474**	.763**	.700**	.580**	1

LA (learning achievements)

Table 12. Regression analysis of learning motivation (A, R, C, S)

	R	R^2	ESD	Modified statistics		
				Variance of R^2	F change	Sig. F change
1	.763	.583	6.567	.513	103.385	.000
2	.825	.681	5.833	.108	27.556	.000

a. Predictors: (Constant), ARCS-R b. Predictors: (Constant), ARCS-R, ARCS-S

Regression analysis on ARCS learning motivation and learning effectiveness

Table 11 shows the stepwise multiple regression analysis. Within the four variables, learning motivation (A, R, C, S), ARCS-R and ARCS-S show significant predictability, with the multiple correlation coefficient= 0.825 and R^2 =0.731. The two variables could explain 73.1% of the learning effectiveness variance, while 26.9% could not be explained.

The analysis of variance (**Table 12**) shows the overall significance of the *F* test, in which F=103.385 (p=.000<.05), 79.178 (p=.000<.05), 68.697 (p=.000<.05), and 64.468 (p=.000<.05), respectively.

With regression analyses, the optimal prediction model is shown below:

Table 13. Hypothesis table results

Hypothesis	Description	Supported
H1	Demographic variables show positive effects in 3D cardiac catheterization game-based learners' learning motivation.	Yes
H2	Demographic variables show positive effects on 3D cardiac catheterization game-based learners' medical anxiety.	Yes
H3	Different learning strategies show positive effects on 3D cardiac catheterization game-based learners' learning motivation.	Yes
H4	Different learning strategies show positive effects on 3D cardiac catheterization game-based learners' learning achievement.	Yes
H5	Learning motivation shows positive effects on 3D cardiac catheterization game-based learners' learning achievement.	Yes
H6	Learning motivation shows positive effects on 3D cardiac catheterization game-based learners' medical anxiety.	Yes
H7	Learning achievement shows positive effects on 3D cardiac catheterization game-based learners' medical anxiety.	Yes

$$\boldsymbol{y_{LP}} = \mathbf{15.070} + \mathbf{11.167} \times \boldsymbol{x_r} + \mathbf{6.429} \times \boldsymbol{x_s}$$

where $\boldsymbol{y_{LP}}$ denotes learning achievements, $\boldsymbol{x_r}$ is the relevance variable of learning motivation, and $\boldsymbol{x_s}$ is the satisfaction variable of learning motivation.

(1). The multiple correlation coefficients of learning motivation ARCS-R, ARCS-S presented .825, showing the two variables are able to explain the 82.0% variance in learning achievement. Such a variance resulted from learning motivation ARCS-R and ARCS-S. The multiple correlation coefficients of the two variables and the learning achievement was .763, indicating that the two variables could explain 76.3% of the variance in learning effectiveness.

(2). In the regression model, ARCS-R presented a larger individual variance, explained by a learning achievement of 51.3%, and was followed by ARCS-S.

Results

The results of hypothesis table (Table 13) show that are all hypothesis were significant.

CONCLUSIONS AND SUGGESTIONS

Conclusions

This study implemented a 3D-CCGBLS for a cardiac catheterization clinical pathway course, finding, after system evaluations, that the learning achievements were significant. The developed system applies a situational-learning, clinical pathway for experimentation by cardiac catheterization students, using a 3D-CCGBLS, e-learning and traditional learning, and discusses the impact of the three learning strategies on the learning achievement, motivation and medical anxiety. The results indicate that all seven proposed hypotheses were of significant value. Some of the findings are provided for reference by the relevant educators:

(1) This study has shown that the learning achievement is not impacted by demographics and gender, which agrees with the conclusion of Ke's study (Ke & Grabowski, 2007).

(2) In the experimental group, students using a 3D-CCGBLS achieved more than they had on the pre-test. The average motivation scale of 4.1>3 highlights the effect of game-based learning with high learning motivation. In the ARCS motivation model, the relevance and satisfaction factor have a strong learning achievement (R Square=.825) predictability.

(3) The experimental group exhibits a higher learning achievement than both control groups. This result shows that the 3D-CCGBLS obviously improves the learning achievement of students.

(4) The best learning achievement model was built with stepwise multiple regressions for learning motivation: $\boldsymbol{y_{LP}} = \mathbf{15.070} + \mathbf{11.167} \times \boldsymbol{x_r} + \mathbf{6.429} \times \boldsymbol{x_s}$.

(5) H7 shows that high learning performance reduces medical anxiety, i.e., knowledge acquisition reduces fear. Thus, effectively enhanced learning could promote learning performance and, conversely, mitigate fear.

(6) Consequently, a game-based learning design should emphasize the relationship between curricula and games, allowing learners to acquire knowledge through games. This means that the integration ability of game-learning can present students with a greater in-depth knowledge of cardiac catheterization.

Suggestion

Based on the research conclusion, suggestions are proposed as a reference for game-based teaching strategies and for future research studies.

(1) Adjust time for game control

Many games impose time restrictions. However, these restrictions often do not allow students to think calmly about the game process. Sufficient time is, therefore, suggested to allow students to understand completely the operation and requirements of the game and to consider the processing in future designs.

(2) Increase the number of deferred tests to understand better the retention rate of the learning effectiveness

After the experiment, only immediate learning effectiveness is tested, but long-term retention is not discussed. Effective instruction should enable students to internalize, thoroughly, the lesson content. For this reason, it is suggested that future studies discuss retention after game-based learning.

(3) Increase the involvement and number of game types as intervening variables to understand the moderating effects on learning effectiveness

As mentioned in the literature review, motivation could enhance learning effectiveness. In this case, future studies could increase involvement and game types as intervening variables to understand the moderating effects on learning effectiveness.

(4) Collect game-based learning big data to establish game-based learning effectiveness prediction models

The cardiac catheterization clinical path instruction is taught with an established 3D-CCGBLS. It is suggested that game-based learning attributes could be collected for a learning effectiveness prediction model with soft computing.

Implications for medical education

This study presents some influence on the medical education of cardiac catheterization operation. First, it helps familiarize the operation of the clinical pathway of cardiac catheterization; second, the situational simulation allows learners reinforcing the knowledge cognitive scheme. Normally, students need to have practical case practice for learning specific knowledge. Simulation practice could reinforce students' situational cognition of cases and the learning cognitive schemes (Van Merrienboer and Kirschner 2012). Although simulation games could enhance the activeness to participate in learning and reinforce the comprehension of learning cognitive scheme, excessive auxiliary learning could easily distract novices and hinder the formal learning. In particular simulation fidelity can easily create cognitive overload for novices. Learning task fidelity should only gradually increase as learners become more proficient (Leppink and van den Heuvel 2015).

It is also found that the motivation to actively participate in learning would positively affect learning outcome, which would further influence medical anxiety. That is, learners with correct and good cardiac catheterization knowledge would comparatively appear less fear on the medical treatment of cardiac catheterization. Besides, the simulation game based teaching strategy shows positive effects on the reinforcement of learning motivation.

Limitations

This study has a number of limitations. First, the sample size of the control group is limited so that comparisons between the control group and the game or cases group may have been underpowered. Considering the assessment scores and confidence intervals around the differences of the experimental groups, larger samples are not expected to change the conclusions. However, in a follow-up study, it is recommended to use larger samples for the control group.

The limit of mobile devices is the second limitation. Since a large number of tablets are required for this study, the participants are grouped to use the inadequate devices at different time intervals. The successive experiments are expected to have adequate devices to complete all experiments and collect data at a time.

Students' past game-based learning involvement, which could also affect learning outcome, is the third limitation. The successive research is suggested to consider game-based learning involvement as an interference factor.

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