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ITOUYING: A SERIOUS GAME FOR LEARNING ORTHOGRAPHIC PROJECTION

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ABSTRACT

Today's student learning style is much different than before. Many researches have shown that games are a powerful tool in many educational domains, but there is no specific research discuss how to use games to strengthen orthographic projection learning. Therefore, the goal of this paper is to investigate what makes orthographic projection learning difficult in vocational education settings, and then design a game to combat these issue. The ITouYing game is composed of seven sub-units, including 1) Orthographic projection concept, 2) Orthographic projection knowledge quiz, 3) Plane type judge, 4) Stain in plane, 5) Proper view selection, 6) Three view match, and 7) Proper 3-D model selection. Results for ITouYing's effectiveness for learning were examined. They indicated that students like to use the ITouYing game, because it can enhance the student's natural' orthographic projection abilities and also is able to improve student visualization skills between 3-D model and multi-view.

Key Words: Vocational education, Orthographic projection, Serious game, Multi-view, 3-D model.

INTRODUCTION

Nowadays, most of students in industrial vocational senior high school are considered Digital Natives(Prensky, 2001), their learning style or learning culture is quite different from their parents and teachers, who are Digital Immigrants(Prensky, 2001). Orthographic projection is a core element of technical/engineering graphics**,** but there are no obvious techniques in learning orthographic projection in industrial vocational senior high school settings. Many previous studies have shown that serious game is a powerful and effective tool in many educational setting, but there is no specific research discuss how using serious game to strengthen orthographic projection learning. This research is to investigate what makes orthographic projection learning difficult in industrial vocational education settings, and then design a serious game, called ITouYing, to help student to master orthographic projection learning.

The systematic five-step ADDIE model(Gagne et al., 2005) is applied to design the ITouYing game. There are the steps of analysis, design, development, implementation, and evaluation (illustrated in Fig. 1), which provide a theoretical framework to discuss solid instructional design techniques for serious game design. In the first step, an engineering graphics learning status and user requirement survey is conducted to investigate the user requirements, needs, and the attitude towards adopting a serious game for learning orthographic projection. The survey results are helpful to the ITouYing game concept design. For step 2, there are nine units was developed in this serious game. After that, in the step 3 an ITouYing game concept usability survey was

conducted. The survey results are used to modify, refine the ITouYing game, and enhance functionality and aesthetic level to meet the digital native students' learning preferences. Steps 4 and 5 content not cover in this paper.

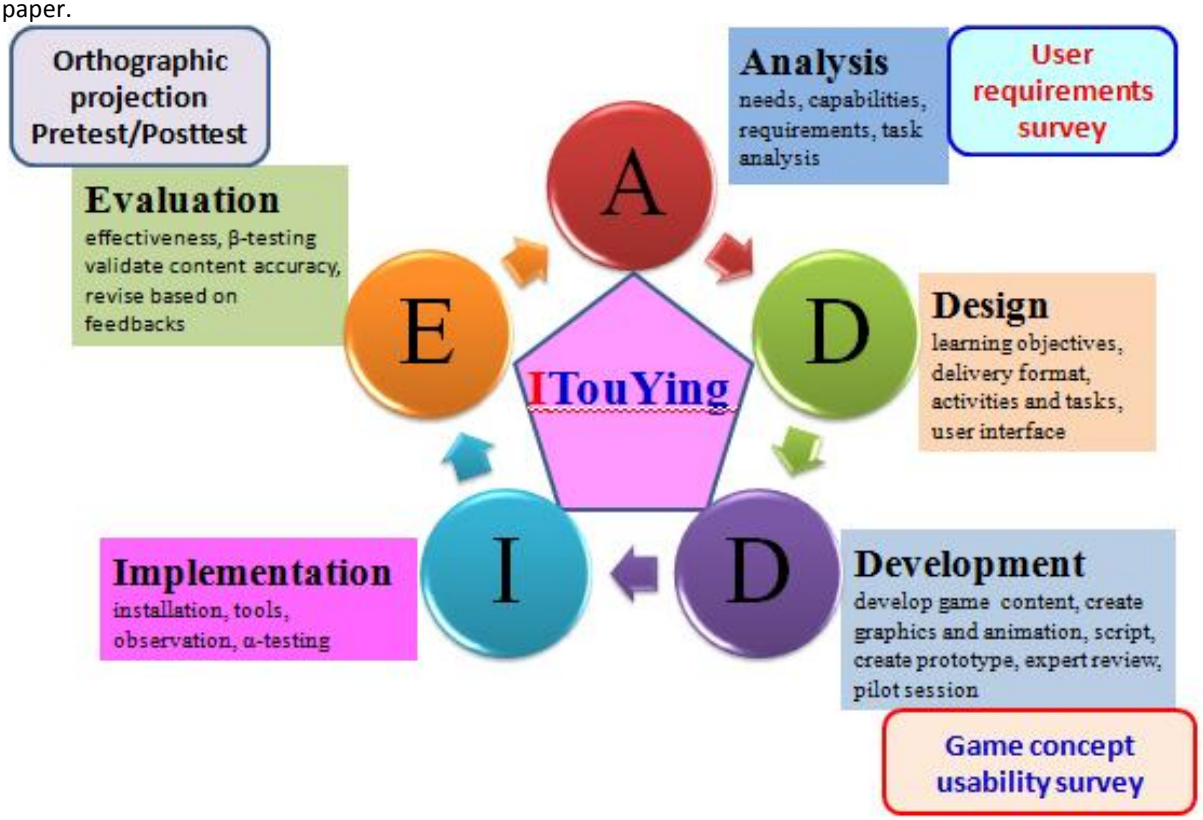

Fig. 1: Systematic five-step ADDIE model

Learning Style Between Digital Native and Digital Immigrant

The most of students in industrial vocational senior high school are Digital Natives (DN)(Prensky, 2001), and part of the games generation (Prensky, 2003), net generation (Tapscott, 1998), iGeneration(Australian Bureau of Statistics, 2009; Rosen, 2010). Most of them carry smart phones and use it to access internet. They finish many activities through smart phone, such as, chat with friends and classmates in Facebook, watch videos on YouTube, play games with friends, share photos with friends in Facebook, Google +, or Flickr, communicate with friends using instant messaging, and so on. The digital natives' learning style is quite different from their digital immigrant parents and teachers. There are ten main cognitive style changes in the Games Generation have observed by Prensky (2007), 1. Twitch speed vs. conventional speed 2. Parallel processing vs. linear processing 3. Graphics first vs. text first 4. Random access vs. step-by-step 5. Connected vs. standalone 6. Active vs. passive 7. Play vs. work 8. Payoff vs. patience 9. Fantasy vs. reality 10. Technology-as-friend vs. technology-as-foe. As the cognitive style changes in the digital native student, the education environment, the learning material deliver channel, and the teaching method and style should change to accommodate the digital native learning style and preferences.

Orthographic Projection

Engineering graphics or Technical graphics is a fundamental and significant course in many engineering and design relative departments at industrial vocational senior high schools, such as mechanical engineering, mechanical drafting, architectural engineering, civil engineering, foundry engineering, Graphic Arts & Communication, refrigeration & air-conditioning, heavy machinery, Mold and Die Engineering, and so on.

Technical/Engineering Graphics is a universal language and a graphic communication skill using in engineering design, industrial design, interior design, medical equipment design, and patents(Bertoline 1995, Giesecke 1985; Wallach 1981; Lin 2004; Wu 2005). Engineers and designers use technical/engineering graphics to

communicate their design ideas to each other and deliver their design to others. A manufacturing engineer according to the technical graphics makes the machine elements and the assembly engineer assembles them to make up a machine or device. It is critical for student to master technical/engineering graphics that benefit their relative course learning and ensure their in-job success in the future.

Orthographic projection is the core element in technical/engineering graphics. Other subjects are based on the orthographic projection, such as isometric view, multi views, Section view, Oblique drawing, Auxiliary views, Intersection & developments, Dimension & tolerance, Working drawing, Pipe drawing, etc. Therefore, if a student wants to master the technical/engineering graphics course, he/she must master orthographic projection.

Computer-Assisted Instruction in Engineering Graphics

As the computer has become the assistive learning tool in the classroom and out of class, there are many researchers developing Computer-Assisted Instruction(CAI) systems for teaching descriptive geometry and engineering graphics. Sueoka et al.(2001) used VRML and JAVA3D to create instruction materials(illustrated in Fig. 2) for training student spatial skills. Their virtual interactive, dynamic 3-D computer-assisted instruction (CAI) platform enhances the freshman's visualization skills in descriptive geometry and graphic science education. Hsu (2006) also developed a computer-assisted instruction system(illustrated in Fig. 3) as supporting material for his course in “Engineering Graphics” at the Mechanical Department of the Northern Taiwan Institute of Science and Technology and Computer.

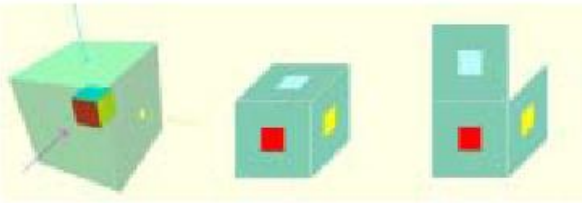

Fig. 2: CAI for understanding the process of orthogonal projection

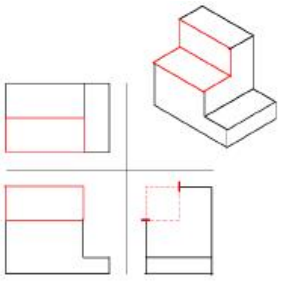

Fig. 3: Computer-assisted instruction forEngineering Graphics.

Rafi et al. (2006) designed an interactive engineering drawing trainer (EDwgT, illustrated in Fig. 4) to investigate the effectiveness of computer-mediated engineering drawing instruction for improving spatial visualization and mental rotation. Their research results indicated that factors such as spatial experience, gender, learning styles, appropriate utilization of instructional method for a particular group can maximize their training efficacy, and their EDwgT trainer system improved student spatial visualization. Cohen & Hegarty (2008) at the University of California, Santa Barbara, used interactive animation and virtual geometric solids(illustrated in Fig. 5) for spatial visualization training. Their research results point out spatial visualization skills can be improved through training and provide evidence for the usefulness of interactive computer visualizations in their training. Their participants were able to infer the shapes of untrained figures by noting similarities among the spatial features of criterion figures and remembering the shapes of their cross sections. Lin, (2004) also designed a descriptive geometry teaching CAI system to assist in teaching. His research indicated that the CAI system can improve student learning effectiveness.

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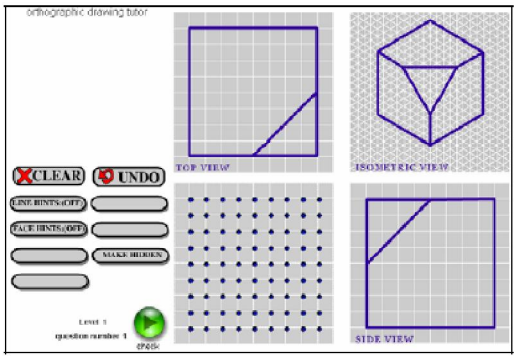

Fig. 4: Interactive engineering drawing trainer (EDwgT)

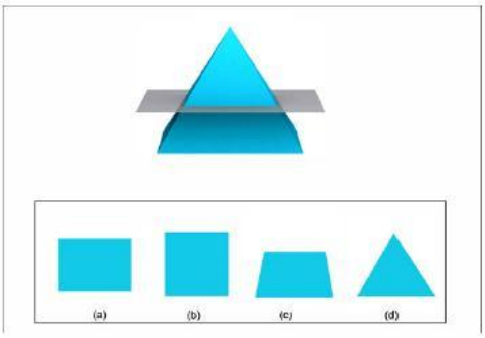

Fig. 5: Interactive animation and virtual geometric solids

Serious Game for Learning Engineering Graphics

Computer games form a part of children's culture (Fromme, 2003), and gaming is relative to their living and learning. According to Zyda (2005), a serious game is defined as ”a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives”. Kinzie & Joseph's (2008) research show that children love to play games and are highly motivated to engage with them. There are many previous researches that show serious game is an effective and powerful educational tool(Michael & Chen, 2006; Kinzie & Joseph, 2008) in many education domains, such as military training(Lim, 2013; Yildirim, 2010), marketing(Devitt et al., 2014), management (Mayer 2006), health care(Ribaupierre et al., 2014; Lynch-Sauer et al., 2011), foreign language learning (Johnson, 2010; Ludwig, Fu, Bardovi-Harlig, & Stringer, 2009), computer programming (Xu, 2009), computer graphics(Mustaro et al., 2009), job-specific skills, politics(Dahya, 2009; Bogost, 2010), etc.

Crown (1999, 2001) had developed a number of web-based games using simple JavaScript code to teach visualization skills needed for a course in engineering graphics. His research findings show that the web-based games significantly reinforce course topics, and student learning outcomes and attitudes about the course improved. Fig. 6 is a screenshot of his game-like test.

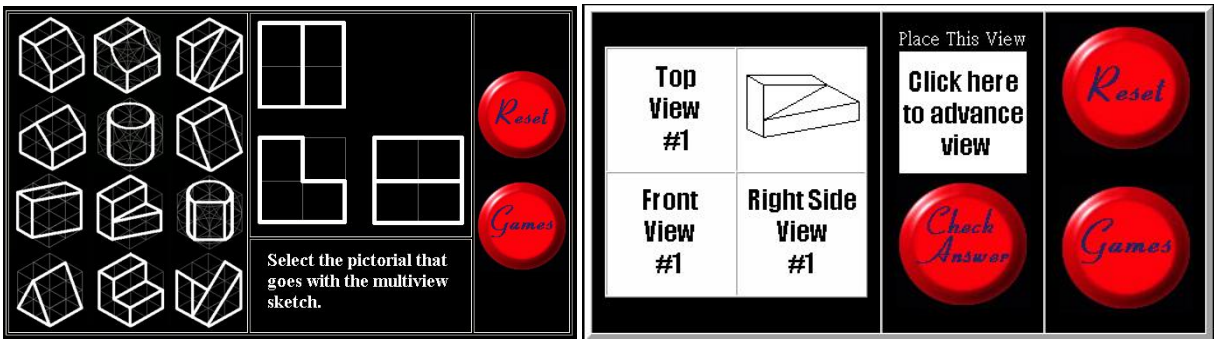

Fig. 6: Screenshot of Crown's game-like test

Engineering/Orthographic Projection Learning Status and User Requirement Survey

According to Maxl & Tarkus (2009), gathering user requirements from the target group is a crucial part in the game development process, this study conducts a user requirements survey for students in the department of mechanical engineering and mechanical drafting at the National Tainan Industrial Vocational Senior High School. Table 1 is the questionnaire about learning engineering/orthographic projection and user requirements.

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There were a total of 224 participants who finished the survey, 194(86.6%) participants are male students, and 30(13.4%) participants are female students. The detailed survey result are shown in Fig. 7. There are about 22% (6.3% strongly agree and 16.1% agree) of the participants who can master both the isometric view and multi views simultaneously, and about 23% (2.7% strongly disagree and 20.5% disagree) participants report they can't. The survey concludes that some student's knowledge and skill of engineering/orthographic projection is under developed. About 50% (24.1% strongly agree and 25.4% agree) participants report they prefer to using serious game for learning orthographic projection. There is high potential to design an innovative serious game for helping students to learn orthographic projection.

Table 1: Orthographic projection learning status and user requirement survey questionnaire

Item	Question	Abbreviate
1	Learning orthographic projection **is fun**	LOPHF
2	I have **master**ed the knowledge of orthographic projection	MKOOP
3	**Keep up with** teacher's progress	KUWTP
4	Drawing multi-views **on time**	DMOT
5	**Need help** for drawing multi views	NHFDM
6	**Missing lines** in drawing multi views	MLIDM
7	Drawing multi-views **easier**	DMME
8	After I finish multi-views, I **can't comprehend the real shape**	AFMBCCRS
9	**More comprehend real shape** by drawing isometric view	MCRSBDIV
10	Drawing isometric view **is easier**	DIVME
11	I have **mastered** multi-views and isometric view	MMAIV
12	I have mastered multi-views but **can't master** isometric view	MMBCMIV
13	I have mastered isometric view but **can't master** multi-views	MIVBCMM
14	I often **teach other student** to draw multi-views and isometric view	OTOSDMIW
15	I **perceive accomplishment** while finish learning multi-views and isometric view	PAWFLMIV
16	I **prefer serious game** for learning orthographic projection	PSGFLOP

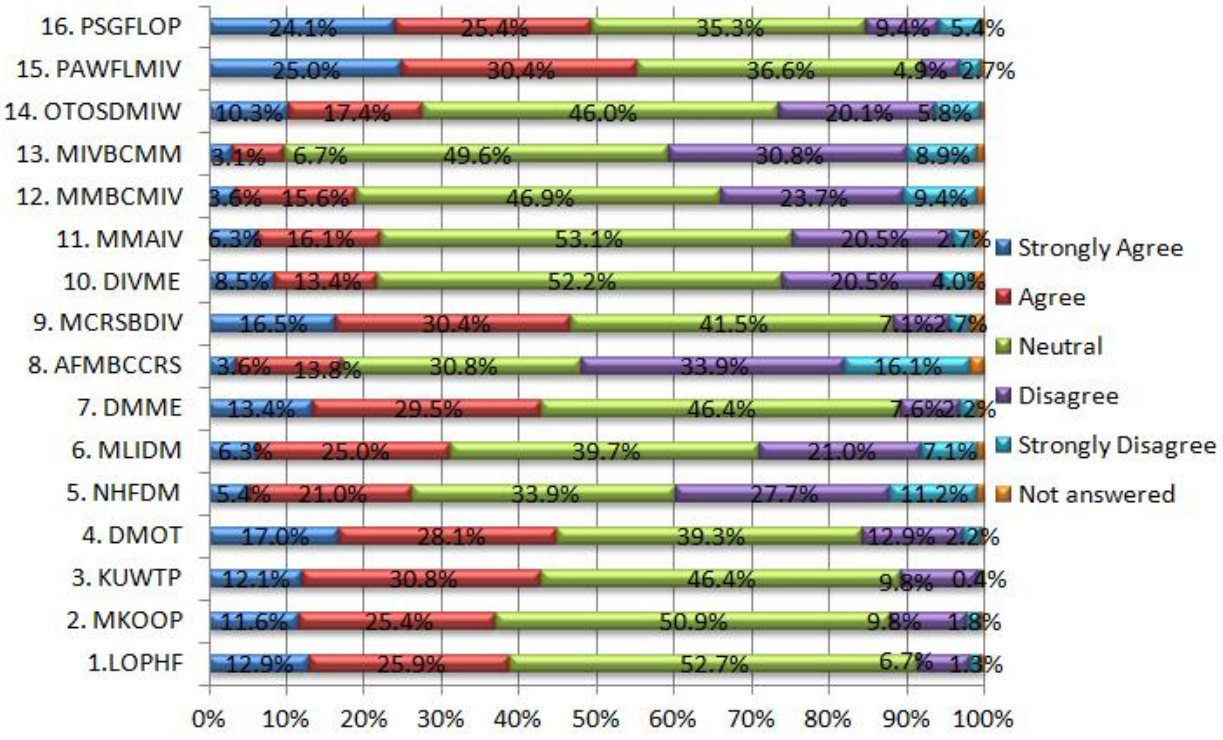

Fig. 7: Survey results of orthographic projection learning status and user requirements

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Designing the ITouYing Game for Learning Orthographic Projection

Based on the literature review and the user requirement survey results, the author designed the ITouYing game for learning orthographic projection. There are nine subunits, including 1) Orthographic projection concept, 2) Orthographic projection knowledge quiz, 3) Plane type judge, 4) Stain in plane, 5) Frontal view selection, 6) Right side view selection, 7) Top view selection, 8) Three view match, and 9) Proper 3-D model selection.

Unit 1 is the orthographic projection concept learning game**.** It uses animation and video clips to introduce the basic concepts of orthographic projection. They cover the main six issues, including 1)Type of plane, 2)Type of projection, 3)Orthographic projection, 4)First angle projection, 5)Third angle projection and 6)Multi-views and isometric view. Fig. 8 illustrates the user interface in orthographic projection concept unit.

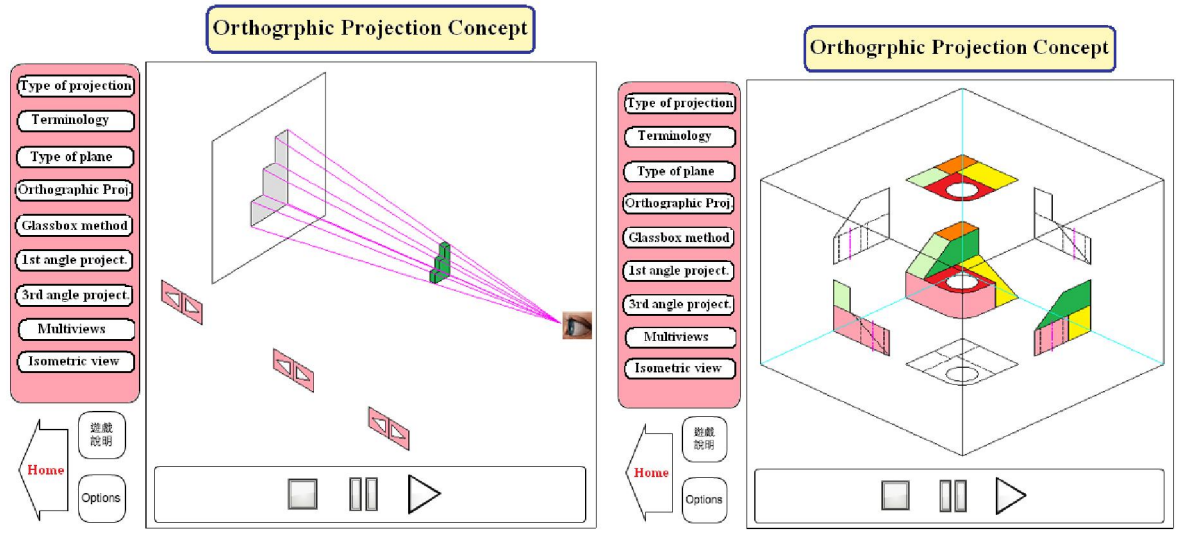

Fig. 8: User interface in orthographic projection concept

Unit 2 is **the orthographic projection knowledge quiz game** with time bonus. It is an in-game assessment unit to assess whether the student/user had mastered the basic orthographic projection knowledge. If the student/user correctly answers the question under the time limit, the student/user will gain additional time bonus points. The quiz game unit also provides a score leader board and speed leader board. This game function can motivate the student/user to keep their attention in a competitive learning environment. Fig. 9 illustrates the user interface in the orthographic projection knowledge quiz game.

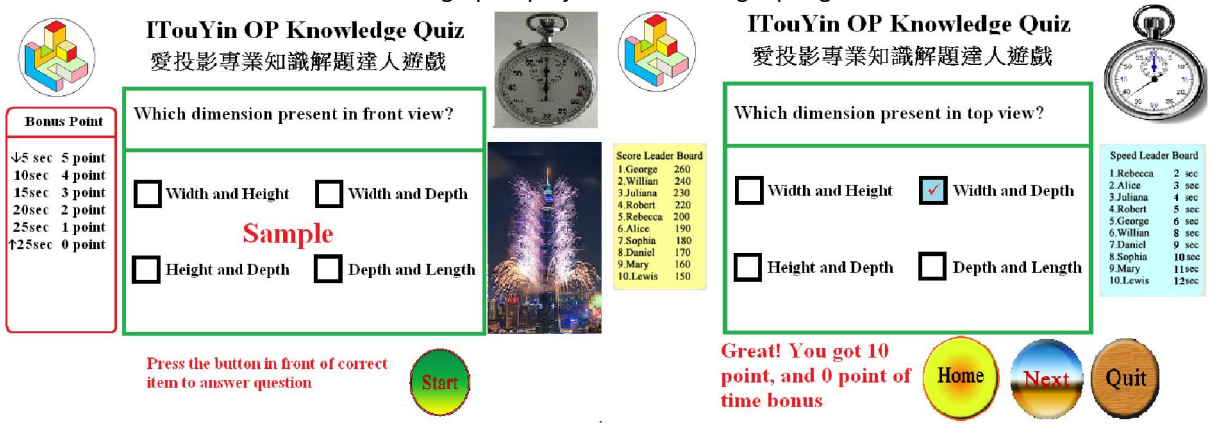

Fig. 9: User interface in Orthographic projection knowledge quiz game

Unit 3 is **plane type judge game**, this sub-game given an isometric view that in each visible plane was marked a different symbol, player should press the correct button for each plane column in the answering area to answer. The user interface of plane type judge game is shown in Fig. 10.

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Unit 4 is **Stain in Plane game**, this sub-game gives an isometric view that in each visible plane is marked with a different color, player should stain the same color at each corresponding plane in the multi-views. The user interface of plane type judge game is shown in Fig. 11.

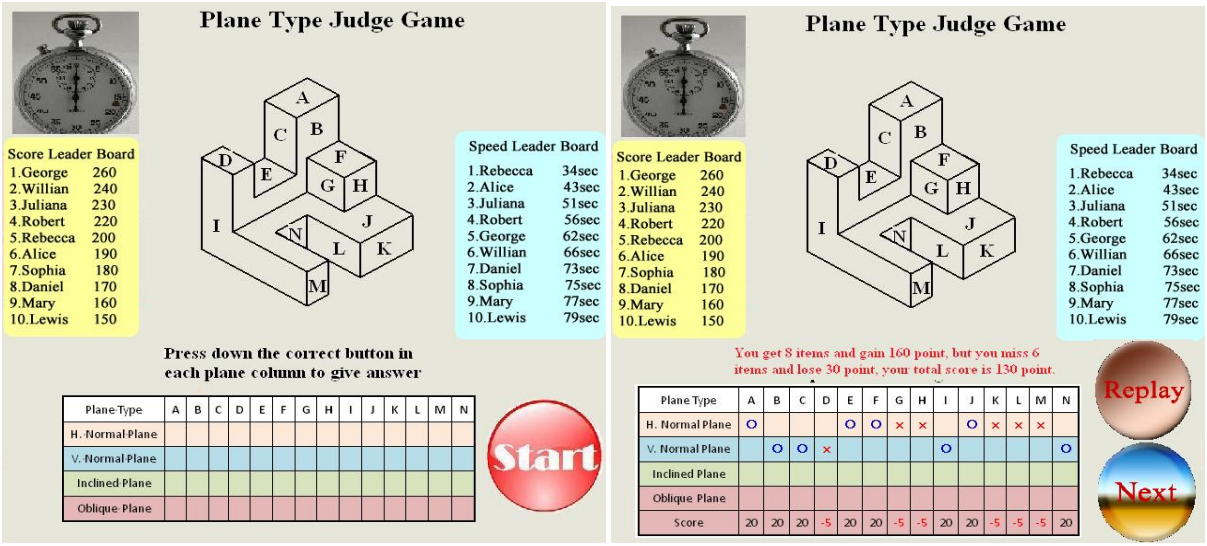

Fig. 10: User interface of plane type judge game

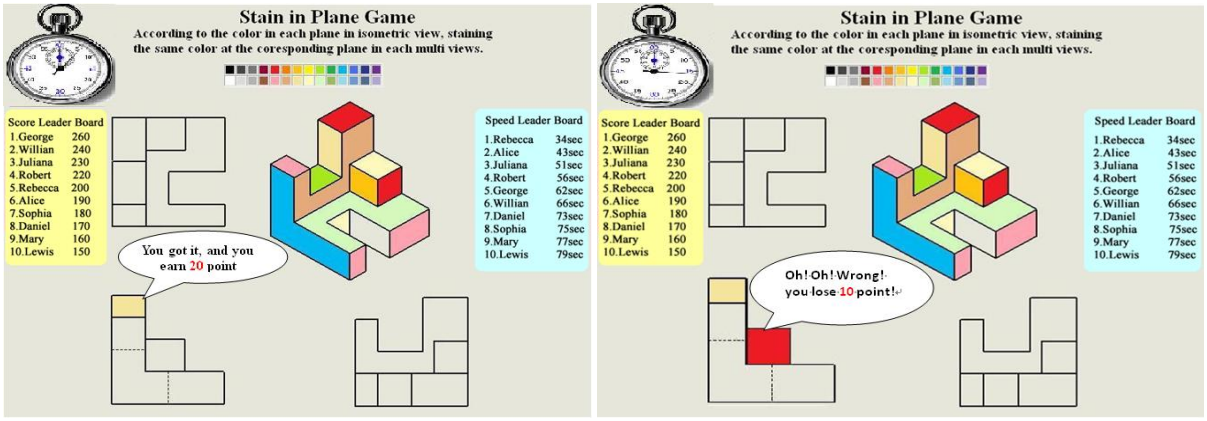

Fig. 11: User interface in stain in plane game

Units 5, 6, and 7, are **proper view selection games**, where the participant should select a correct view from the six candidate views according to the assigned projection direction about a given isometric view. This subunit game is to examine whether the participant has acquired the visualization skill from an isometric view (or 3D model) to transform into a multi view. The user interface of units 5, 6, and 7 are shown in Figs. 12, 13, and 14.

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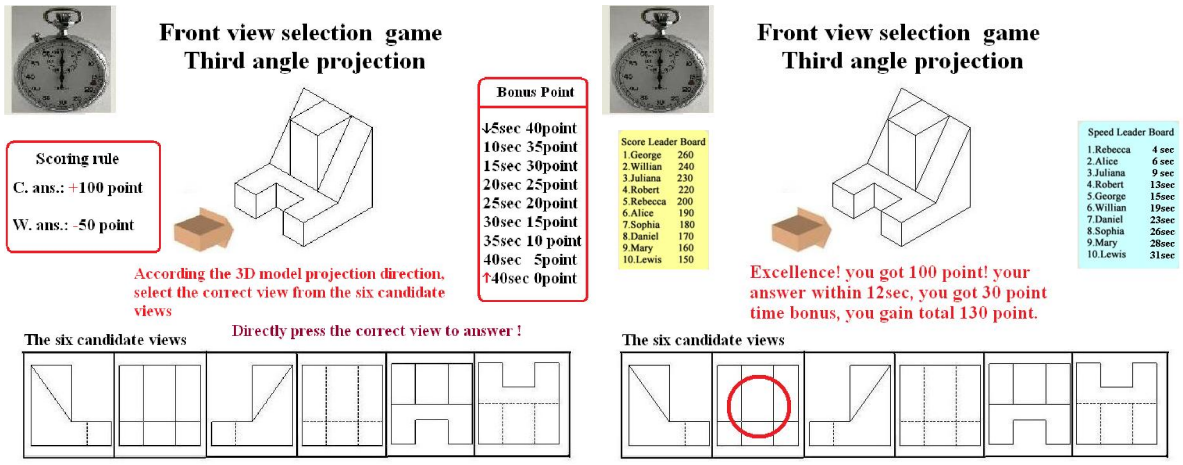

Fig. 12: User interface of Unit 5 -- Front view selection game

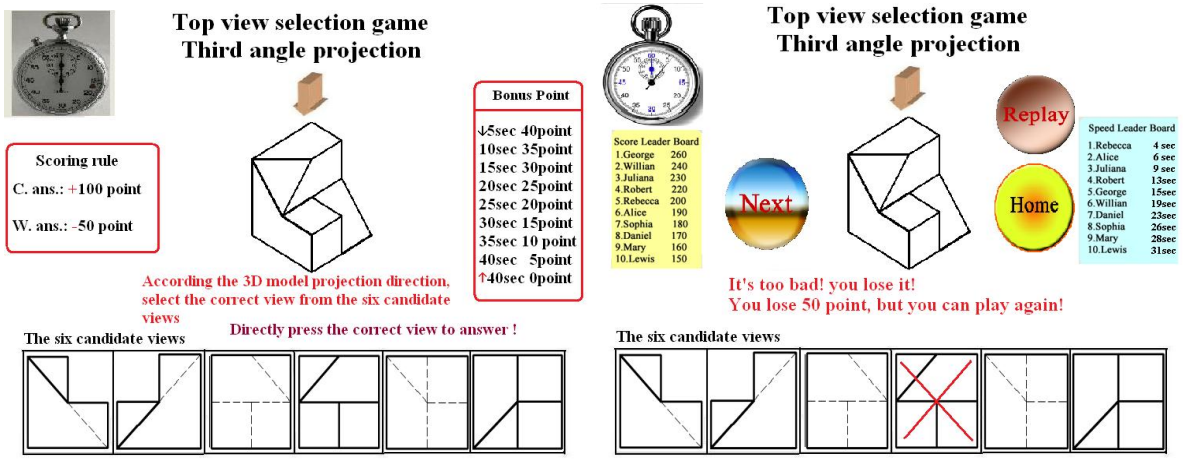

Fig. 13: User interface of Unit 6 -- Top view selection game

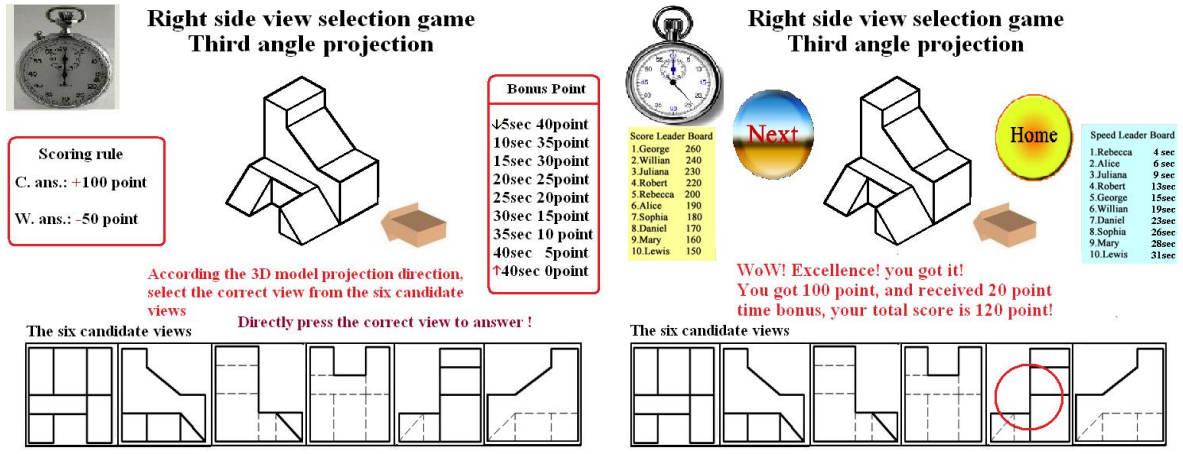

Fig. 14: User interface of Unit 7 -- Right side view selection game

The unit 8 of ITouYing game is **three view match game**. This unit gives an isometric view and assigned the frontal projection direction, and the user must drag the correct view(front view, top view, right side view) according to the given information and drop it into the corresponding position. The user interface of three view match game is shown in Fig. 15.

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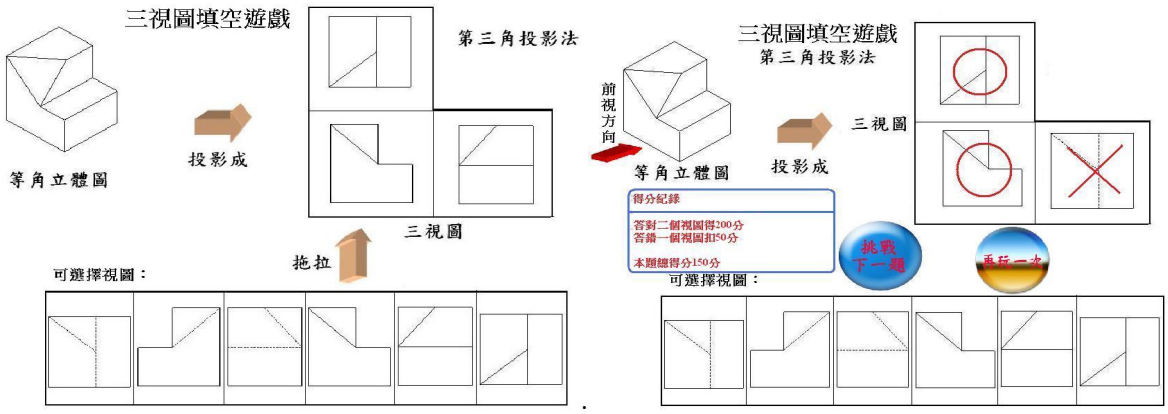


Fig. 15: User interface of unit 8 -- three view match game

The last unit of the ITouYing game is **proper 3-D model selection game**. This subunit game provides multi-views, and the user should select a corresponding correct 3-D model (or isometric view) from the 3-D model inventory according to the given multi-views. The user interface for the proper 3-D model selection game is shown in Fig. 16.

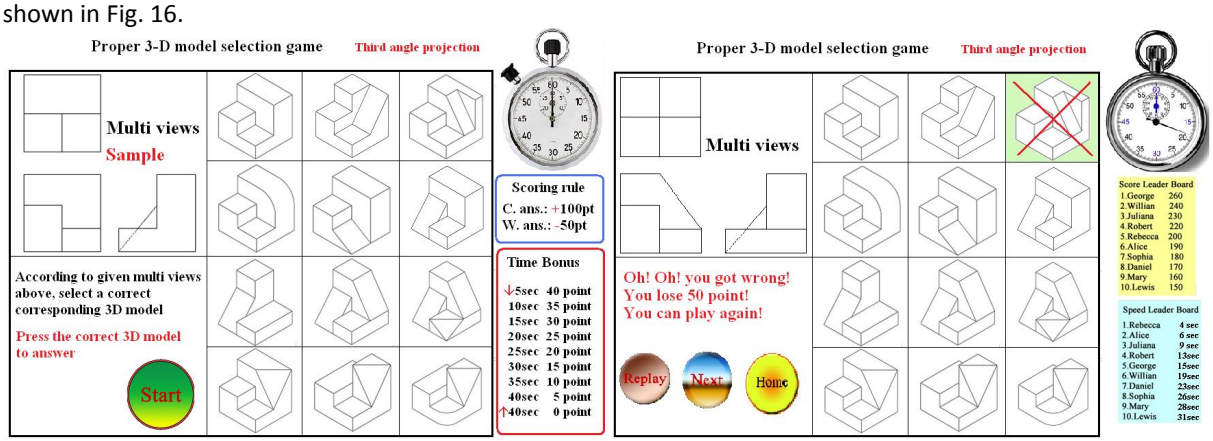
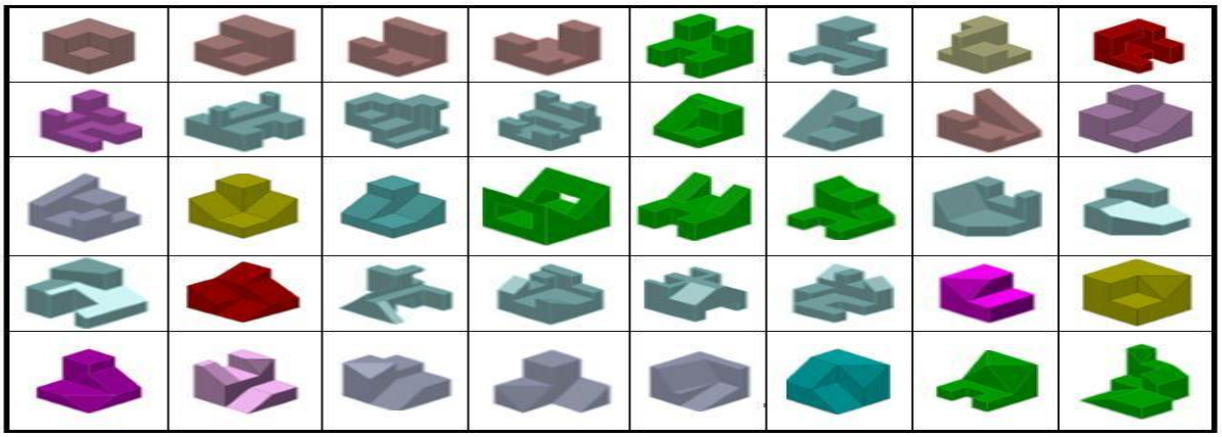


Fig. 16: User interface of unit 8 -- three view match game

There are about two hundred 3-D models in the ITouYing game inventory. Table 2 lists a sample of the 3-D models in the game inventory. Each 3-D model in the model inventory will be randomly assigned to each unit for different difficulties of ITouYing according to the complexity in face number and face type combination.

Table 2: Sample of the 3-D models in the game inventory



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METHOD

Participant Demographic Information

After the nine subunits of the ITouYing game concept had been designed, the ITouYing game concept survey is conducted. This survey collected participant data from three industrial vocational senior high schools in Tainan city. The participants are 7-9 grade students who major in mechanical engineering or mechanical drafting departments. Of the 161 total participants, 135(83.9%) participants were male students, and 26(16.1%) participants were female students. The participant detailed demographic information is listed in Table 3.

Table 3: Participant demographics of the ITouYing game concept survey

School	Department	Grade	Age	Male	Female	Total
NTIHS	Mechanical Drafting	7	15-18	29	12	41
NTIHS	mechanical engineering	7	15-18	40	0	40
NTIHS	mechanical engineering	8	15-18	38	0	38
NXIVHS	Mechanical Drafting	7	15-18	10	5	15
NXIVHS	Mechanical Drafting	8	15-18	8	7	15
ASIVCEHS/NCKU	Mechanical Drafting	9	15-22	10	2	12
Total				135	26	161
NTIHS	National Tainan Industrial High School					
NXIVHS	National XinYing Industrial Vocational high school					
ASIVCEHS/NCKU	The Affiliated Senior Industrial Vocational Continuing Education High School of National Cheng Kung University					

Questionnaire in ITouYing Game Concept Survey

For the ITouYing game concept survey, there were 13 questionnaires used to investigate the usability and user interface of the ITouYing game concept. These included whether the ITouYing game motivated participants to learn orthographic projection, enhance learning effectiveness, promote visualization skill, ease of use, challenge to play, image beautiful, smoothly usage, fascinating play, creative design, reasonable rules, high achievements, great effort to master, glad to introduce to a friend. The questionnaires and it abbreviations are listed in Table 4.

Table 4: The ITouYing game concept close-end survey questionnaire and its abbreviations

Item	Question	Abbreviate
1	1. The iTouYing motivate to learn orthographic projection	1. MTL
2	2.The iTouYing enhance the learning effectiveness of orthographic projection	2. ELE
3	3. The iTouYing promote the visualization skill between 3D model and multiviews	3. PVK
4	4. The iTouYing serious game is easy to use	4. ETS
5	5. Playing iTouYing is challenging	5. PIC
6	6. The image of iTouYing is beautiful	6. IIB
7	7. The use of iTouYing is smoothly	7. UIS
8	8. Playing iTouYing is fascinating	8. PIF
9	9. The design of iTouYing is creative	9. DIC
10	10. The rules of iTouYing is reasonable	10. RIR
11	11. Playing iTouYing is highy achievement	11. PIHA
12	12. I make great effort to master the iTouYing	12. MGFMI
13	13. I am glad to introduce the iTouYing to my friends and classmates	13. GIIFC

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Data collection and Analysis

In order to collect participant opinions and attitudes about the ITouYing game concept, the 5 point Likert scale is adopted in the close-end survey questionnaire. There are 4 open-end questions administrated to the participants to collect their opinion about the advantages and disadvantages of the ITouYing game concept, the most satisfied unit and the most helpful unit of the ITouYing game concept. After that, the close-end survey data is input to an Excel worksheet. The data is grouped into some categories according to the gender, department, school location, daily internet access time, daily gaming time. The t-test is used to check whether the gender, school location, department, daily internet access time, or daily gaming time are significant factors that influence their attitudes toward the ITouYing game.

FINDINGS

The ITouYing game concept survey result is listed in Table 5 and Figs. 17 and Fig. 18 show the agree vs. disagree in the **ITouYing** survey results. From the survey results, this study concludes that the ITouYing game can promote participant visualization skills between isometric view and multi views(agree 80.1%, strongly agree 36%, agree 44.1%). The ITouYing game can enhance participant learning effectiveness in learning orthographic projection(agree 76.4%, strongly agree 34.2%, agree 42.2%). The IToYing game is easy to use(agree 74.5%, strongly agree 28%, agree 46.61%). The rules of the ITouYing game are reasonable(agree 72.7%, strongly agree 33.5%, agree 39.1%).

Table 5: ITouYing game concept survey results

Item	Strong Agree		Agree		Neutral		Disagree		Strong Disagree	
1. MTL	30	18.6%	53	32.9%	64	39.8%	7	4.3%	7	4.3%
2. ELE	55	34.2%	68	42.2%	32	19.9%	1	0.6%	5	3.1%
3. PVK	58	36.0%	71	44.1%	27	16.8%	1	0.6%	4	2.5%
4. ETS	45	28.0%	75	46.6%	31	19.3%	7	4.3%	3	1.9%
5. PIC	30	18.6%	57	35.4%	54	33.5%	12	7.5%	8	5.0%
6. IIB	18	11.2%	32	19.9%	85	52.8%	17	10.6%	9	5.6%
7. UIS	23	14.3%	59	36.6%	70	43.5%	3	1.9%	6	3.7%
8. PIF	34	21.1%	36	22.4%	74	46.0%	7	4.3%	10	6.2%
9. DIC	34	21.1%	61	37.9%	56	34.8%	7	4.3%	3	1.9%
10. RIR	54	33.5%	63	39.1%	36	22.4%	3	1.9%	5	3.1%
11. PIHA	32	19.9%	34	21.1%	76	47.2%	8	5.0%	10	6.2%
12. MGFMI	12	7.5%	13	8.1%	66	41.0%	34	21.1%	36	22.4%
13. GIIFC	29	18.0%	29	18.0%	79	49.1%	7	4.3%	9	5.6%
Total	454		651		750		114		115	
Mean	35		50		58		9		9	

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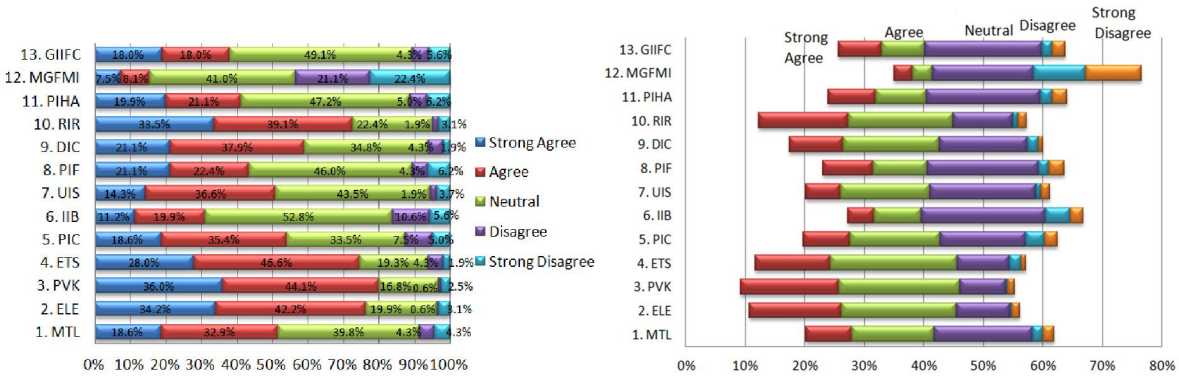

Fig. 17: ITouYing game concept survey results

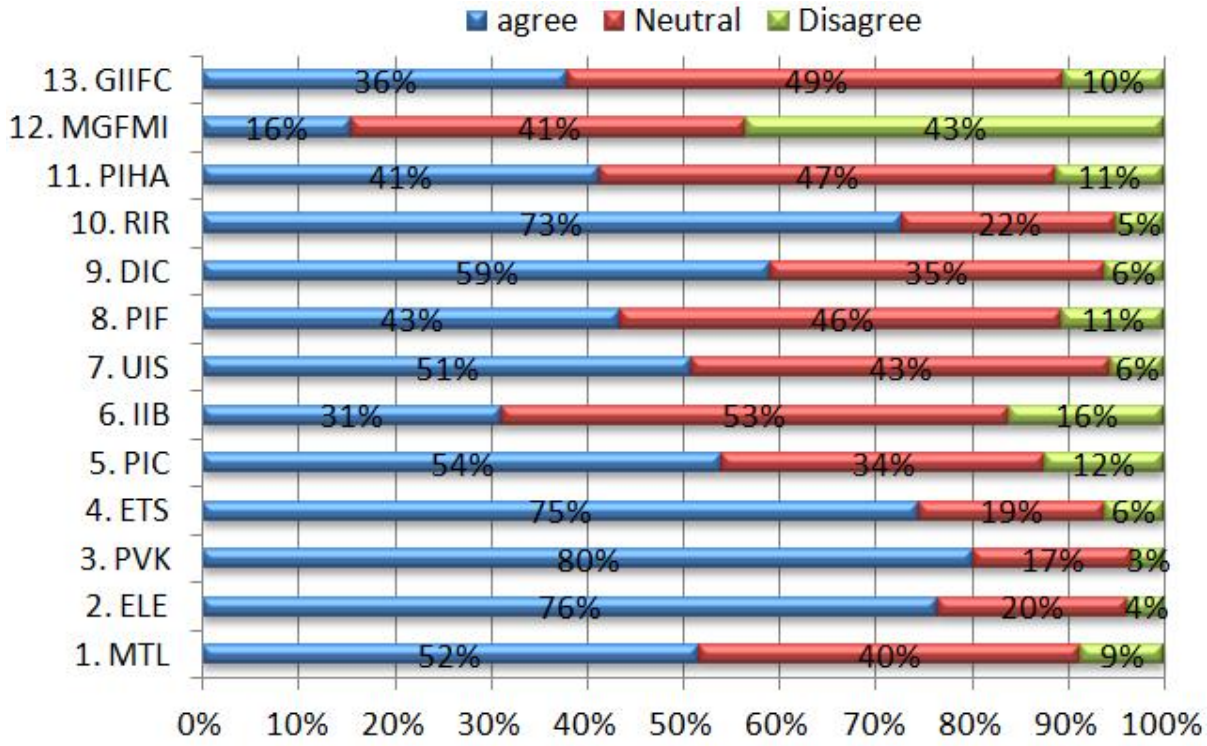

Fig. 18: The agree vs. disagree in the **ITouYing** survey

After data analysis, this study finds that there are significant gender differences in 7 items(illustrated in Table 6) among the ITouYing game concept survey. Female students perceive the ITouYing game can motivate them to learning orthographic projection, the ITouYing game enhance the learning effectiveness, the ITouYing game can promote the visualization skill between 3-D model(or isometric view) and multi-views, the ITouYing game is easy to use, the use of ITouYing is smooth, playing ITouYing game is fascinating, and the rules in ITouYing game are reasonable, as compared to male students. Moreover, this study finds that school location, department, daily internet access time, daily gaming time are not significant factors influencing participant attitudes toward the ITouYing game.

Table 6: Significant gender differences in ITouYing game concept survey

Item	M-mean	F-mean	M-SD	F-SD	M-Variance	F-Variance	P value (two-tail)
1. MTL	2.485	2.120	1.02	0.71	1.049	0.527	0.037*
2. ELE	2.030	1.600	0.95	0.64	0.916	0.417	0.007**
3. PVK	1.948	1.600	0.9	0.7	0.817	0.500	0.037*
4. ETS	2.112	1.720	0.92	0.72	0.852	0.543	0.025*
5. PIC	2.478	2.240	1.06	0.92	1.124	0.857	0.257
6. IIB	2.843	2.520	0.96	0.99	0.930	1.010	0.147
7. UIS	2.515	2.080	0.9	0.74	0.823	0.577	0.015*
8. PIF	2.619	1.960	1.08	0.85	1.170	0.707	0.001**
9. DIC	2.313	2.080	0.93	0.8	0.863	0.660	0.206
10. RIR	2.082	1.680	0.98	0.79	0.963	0.643	0.033*
11. PIHA	2.619	2.240	1.06	1.05	1.125	1.107	0.107
12. MGFMI	3.418	3.480	1.16	1.07	1.358	1.177	0.797
13. GIIFC	2.604	2.320	1.02	1.02	1.038	1.060	0.213

* P ≤ 0.05 ** P ≤ 0.01

The Most Satisfied Unit and the Most Helpful Unit

According the open-end questionnaire data analysis, the most satisfied unit is unit 4, the participants perceive that stain in plane unit is most satisfied in learning orthographic projection. The second most satisfied unit is unit 9, where selection of proper 3D model(or isometric view) is tested according to the given multi-views. Furthermore, the participants perceive that the three view match unit(unit 8) is most helpful in learning orthographic projection and units 1 and 8 are helpful in learning orthographic projection.

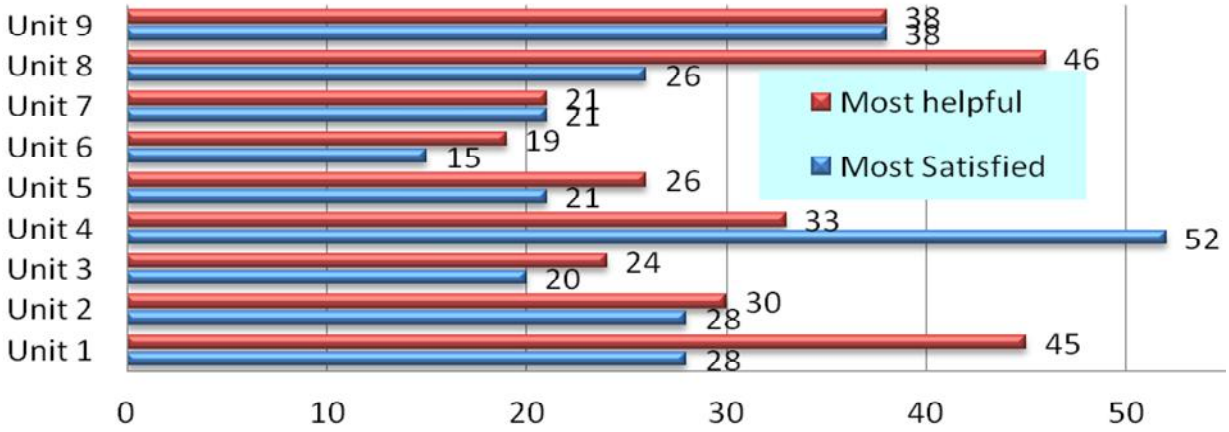

Fig. 19: The most helpful unit and the most satisfied unit

CONCLUSION

From the ITouYing survey results, there are some advantages of the ITouYing Game, including: 1) ITouYing enhances student visualization skills between isometric view(or 3D model) and multi-views. 2) ITouYing improves effectiveness in learning orthographic projection. 3) ITouYing is easy to use. 4) The rules(game mechanic) of ITouYing are reasonable. 5) The design of ITouYing is creative. 6) Playing ITouYing is challenging. 7) ITouYing motivates students to learn orthographic projection. In contrast, there are some disadvantages of

the ITouYing Game, including: 1) The images of ITouYing are less beautiful, it can't catch the students eye 2) Playing ITouYing is less fascinating, there is no story in it. 3) Playing ITouYing is not high achievement. 4) Playing ITouYing is not smooth. 5) Participants don't strongly recommend ITouYing to their friends and classmates.

DISCUSSION AND SUGGESTION

Only 22% of the students master both the isometric view and multi views. This approach has highly potential to design an innovative serious game for learning orthographic projection. The Digital Native student had experienced many beautiful, fascinating, and charming video games previously. How to design an attractive serious game for educational purpose is a tough mission for a Digital Immigrant teacher**.** The serious game design team should recruit Digital Native members who have expertise in visual arts, visual communication, visual effects, and animation skill to meet the learning preferences of Digital Native students. The participants come from three industrial vocational high schools in Tainan city(Taiwan), so the findings and conclusion of this study may not be generalized to all industrial vocational high school in Taiwan.

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