Improving Authentic Learning by AR-Based Simulator

Xiaodong Wei[1](✉), Dongqiao Guo[1], and Dongdong Weng[2]

[1] School of Educational Technology, Northwest Normal University, 967 Anning East Road, Lanzhou 730070, People's Republic of China
wxd1633@163.com

[2] School of Optoelectronics, Beijing Institute of Technology, No. 5, South Zhongguancun Street, Haidian Zone, Beijing 100081, People's Republic of China

Abstract. In this paper, a simulator based on augmented reality is developed, named ARFLY, for use in China's general high school technology curriculum to improve the authentic learning experience and learning effect. ARFLY replaces a real instrument panel, which is complex and expensive, with a virtual 3D model by means of AR technology. ARFLY includes video see-through head mounted display with a motion tracker to realize 360-degree viewing by relating head tracking information to the display of virtual 3D scenarios. In addition, ARFLY is equipped with an intelligent tutoring system that guides the learning process. A pilot study and questionnaire-based evaluation of ARFLY are conducted. The results of a pilot study show that the proposed simulator can enhance authentic feeling, the immersion sensation, and learning motivation for users when learning control principles.

Keywords: Augmented reality · Learning strategies · Secondary education

1 Introduction

Virtual reality (VR) is a system in which users are immersed in a simulated environment and cannot view the outside world. In contrast, augmented reality (AR), also known as mixed reality (MR), enables users to observe virtual objects that are superimposed on or combined with the real world. That is, AR supplements reality, rather than completely replacing it [1]. AR systems are characterized by the following properties: they combine real and virtual objects in a real environment; they align real and virtual objects with each other; and they operate interactively and in real time [2]. These characteristic benefits enable educators and designers to superimpose virtual graphics over real objects, thereby enabling users to interact with digital content through physical manipulation. This facilitates more effective demonstrations of spatial and temporal concepts and the contextual relationships between real and virtual objects [3].

In view of the above advantages of AR, we direct students to operate a flight simulator with which they can experience the flight process and understand the principles of control. AR can improve authentic learning in high school because: (1) the immersion, interaction, and navigation features of AR improve students' motivation to learn, assist

Y. Wang et al. (Eds.): IGTA 2018, CCIS 875, pp. 124–134, 2018.
https://doi.org/10.1007/978-981-13-1702-6_13

them with knowledge comprehension, and are potentially useful in learning tasks that require experimentation, spatial ability, and collaboration [4–6]; (2) AR can reduce the cognitive workload by integrating multiple sources of information while learning [7]; (3) AR can reduce the cost of experimental courses; in terms of product design, it is becoming a major part of the prototyping process [8] and offers a solution to the expensive problem of building prototypes [9]; and (4) AR can provide more varied interactive modes [10].

Considering the unsatisfactory general technology situation in high schools in China, we applied AR technology to the learning of basic flight control principles in the general technology curriculum. Two constraints currently exist in traditional flight control teaching methods. For one, flight simulators used for actual flight training are relatively expensive. Consequently, owing to the lack of financial support for high school laboratories, students are not afforded the opportunity to use a real flight simulator to study basic flight control principles in authentic learning. Secondly, existing flight simulation games used in authentic learning make it difficult for students to experience a true sensation of flight, such as flying over mountains and operating an aircraft while seated in a real cockpit. The relevant learning effects are too difficult to be achieved because the games are not equipped with an instructional system for learning basic flight control principles.

To address the above problems and improve the authentic learning experience, we developed the ARFLY low-cost flight simulator. Based on AR technology, ARFLY includes an intelligent tutoring system (ITS) that guides the learning process. To evaluate students' authentic feeling, immersion sensation, and learning motivation when using ARFLY, we conducted a pilot study at a high school affiliated with Renmin University, China. We designed and implemented a related questionnaire based on situated learning and flow theory, as well as a questionnaire that evaluated students' comprehension of aircraft component functions and control principles. In Sect. 4, we present the results of our evaluation.

2 Literature Review

2.1 Augmented Reality Flight Simulator

The idea of VR has been the cornerstone of simulation since 1965, when Sutherland conceptualized the visual interface as less of a screen than as a window to a virtual world that looks real, sounds real, and reacts in real time [11]. Flight simulation with VR technology still relies on large, cumbersome, and expensive environments to produce a convincing virtual world: vision is enabled through expensive cameras and almost real-life cockpit avionics; pilot controls are mounted on cockpit-like structures; and the whole structure is moved by heavy, primarily hydraulic-driven motion platforms [12]. Currently, it is still rare for AR to be used to display cockpit avionics. Because AR can naturally superimpose virtual objects on real scenarios, a low-cost aircraft cockpit model can be manufactured that superimposes virtual 'real cockpit avionics'—the most expensive components in the aircraft—on this model with AR technology. Moreover, a virtually real operating scenario can be created through which both the actual manual operation and virtual flying scenes outside can be viewed. Thus, applying AR can reduce the costs of the traditional flight simulator while providing sufficient simulation flight effects. Furthermore, the relevant teaching content can be superimposed on the corresponding positions in the cockpit to achieve a better learning effect.

2.2 Intelligent Tutoring System

An intelligent tutoring system (ITS) is a computer system that provides immediate and customized instruction or feedback to learners typically without intervention from a human teacher [13], thereby fostering learning in meaningful and effective ways. A close relationship exists between intelligent tutoring and cognitive learning theories. There are many examples of ITSs being used in both formal educational and professional settings that have demonstrated their capabilities and limitations.

Schiaffino et al., for example, designed eTeacher, an intelligent agent that supports personalized e-learning assistance. The agent builds student profiles while observing student performances in online courses; the information is then used to suggest personalized strategies to assist student learning processes [14].

Another example of a student-centered ITS is ZOSMAT [15]. It follows the work of students and guides them in different learning stages by recording their progress. It then alters the given program based on the student's performance. ZOSMAT can be used for either individual learning or in a real classroom with the guidance of a human tutor.

3 Method

In this section, we describe the ARFLY system structure and components. We explain the design of its ITS, introduce key aspects of the pilot study, and outline the experiment. We then describe our method for assessing ARFLY's learning effects.

3.1 Flight Simulator for Control Principle Instruction

System Design. ARFLY consists of a full-scale cockpit model, cube green screen, liquid crystal display (LCD) monitor, a video see-through head mounted display (VSTHMD), a Saitek pilot control stick and pedal set (http://www.saitek.com/), and a standard desktop PC. The VSTHMD is comprised of a Sony HMZ-T1 HMD (http://www.sony.com/), Logitech HD Pro C920 webcam (http://www.logitech.com/), and Xsens MTi 10-Series motion trackers (http://www.xsens.com/). The PC runs Windows 7 operating systems and is equipped with Intel Haswell i7 CPUs with relatively high-end graphics cards (NVIDIA GTX770 or better). The HMD motion tracker calculates the angular position of the display and feeds it to the computer; the webcam acquires real images and feeds them to the computer. A virtual instrument panel is superimposed on the instrument panel sticker within a real cockpit, which is used as a tracking marker.

The pilot controls are simple joysticks; the center joystick represents lateral and longitudinal cyclic controls; the side joystick denotes collective control, and its slider controls throttle; and pedals represent the tail rotor control.

The ARFLY system structure is illustrated in Fig. 1. A game engine is the core component. Firstly, the VSTHMD webcam transmits real images of the green screen and cockpit interior to the tracking module, which calculates the position and rotation of the virtual instrument panel in a real scenario according to the captured images. Based on this position and rotation, the game engine superimposes the virtual instrument panel on the real instrument panel sticker within the cockpit. Meanwhile, the tracking module transmits the real-time images to the green screen key module. The module makes the images transparent by deducting the green color data; the processed images are then transmitted to the game engine. From that point, the game engine superimposes the transparent images on all virtual and real scenarios.

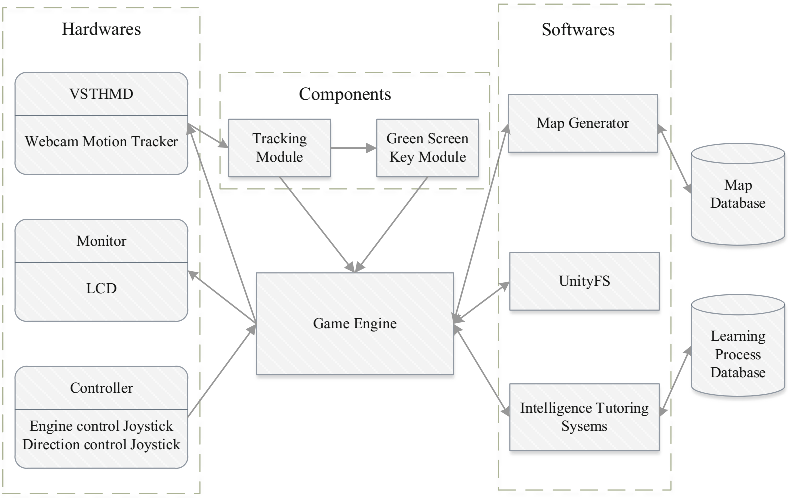

Fig. 1. ARFLY system structure. (Color figure online)

With the above interactive mode, users can view both real cockpit interior scenarios and virtual ones outside the cockpit through the transparent images. Users can simultaneously observe the virtual instrument panel, as shown in Fig. 2(a). In addition, the corresponding dynamic flight scenarios can be rendered through the game engine according to the head motion data recorded by the VSTHMD motion tracker. The ARFLY simulator features a synthetic visual environment as perceived from the pilot's cockpit view. The user has a 360-degree view of the cockpit interior and world surrounding the aircraft through the VSTHMD. This includes pilot controls, cockpit instruments, main rotor rotation, etc. The whole visual environment is integrated through the Unity FS (http://unityfs.chris-cheetham.com/) simulation plug-in. The pilot transmits operation commands through the controller joystick to the game engine. Owing to AR technology, the pilot can observe both his/her manual operations and the virtual instrument panel, as shown in Fig. 2(b). The game engine displays on the LCD monitor the virtual flight scenarios that the pilot perceives in the VSTHMD; therefore, other students can watch. A map generator calculates map data according to the aircraft flight position, calls the given map from a map database, and superimposes it on the flight scenario. When the ARFLY simulator runs, ITS combines multimedia resources stored in the learning process database; rendered by the game engine, these reconstruction resources can guide learning. We developed the flight game, GAMEFLY, to investigate the learning effects of ARFLY. It is similar to flight simulation computer games that do not use a cube green screen, real cockpit, joystick, motion tracker, or HDM. The 3D flight scenarios used in GAMEFLY are the same as those in ARFLY. When playing the game, students view scenarios through the LCD panel but operate the game with a keyboard.


(a) (b)

Fig. 2. ARFLY display effects. (Color figure online)

Intelligent Tutoring System. The ITS module in ARFLY guides students in accomplishing various flight missions. The module includes eight flight missions designed in varying difficulty levels. These step-by-step exercises familiarize students with aircraft component functions. Missions 1 to 3 help students learn the functions of elevation and landing gear, the yaw rudder, and the aileron by practicing basic aircraft operations. Missions 4 and 5 help strengthen the learned skills and give the sensation of flying over water and hilly terrain. Missions 6 and 7 guide students in completing more complex flight operations, such as controlling the aircraft during inverted flight. Mission 8 teaches students the importance of the left and right engines and emulates the experience of crashing. A reality explanation video for the latter mission is displayed on the virtual instrument panel with AR technology, as shown in Fig. 2(a), which gives students the feeling of being directed by a real commander. After assessing the completion of a mission, ITS displays a relevant guidance video prepared from the learning resource database, which includes the assigning of new operating missions and a completion notification. The game engine calculates the aircraft altitude, speed, flight time, angle, engine state, and landing gear status to determine the tasks to be achieved; it then notifies ITS to conduct the next task in the schedule. The next operation is initiated only when the former task is complete.

3.2 Participants

We conducted a pilot study to investigate the effect of ARFLY on authentic learning for high school students. From this level, we randomly selected for our study 24 students from 14 classes and placed them in two groups: Group 1 was the control group; Group 2 was the experimental group. Each group was comprised of eight boys and four girls. For Group 1, conventional teaching methods with GAMEFLY were used; as a comparison, Group 2 used only ARFLY.

3.3 Procedure

In this section, we describe our experimental processes. We used general technical teaching procedures as a reference. The proposed ARFLY learning processes were undertaken by Group 2 in three steps. First, the teacher provided a PowerPoint presentation and flight video to respectively explain and illustrate the basic principles of flight control.

The teaching contents include aircraft flight attitude, the composition of the aircraft control system, the working process of the aircraft control system and interference of flight control (http://www.rbloc.cn/). Second, students were then directed to draw a detailed sketch of an aircraft and apply basic flight control principles to analyze how each component works and controls the aircraft. At last, students were directed to operate ARFLY; the study scenario is shown in Fig. 3. The conventional teaching method used by Group 1 was similar to the ARFLY learning method in its first two steps; however, in the last step, Group 1 students played GAMEFLY. At the end of the pilot study, all participants were required to complete two questionnaires that respectively assessed their comprehension and learning experience. Participants were additionally required to complete a comprehension questionnaire before the pilot study to set a baseline.

(a) (b)

Fig. 3. Learning process using ARFLY: (a) whole learning scene; and (b) local cockpit operating scene.

3.4 Measurements

In an authentic learning environment, student authentic feeling, immersion sensation, and learning motivation play a significant role in teaching effects. We therefore designed the learning experience questionnaire based on situated learning, flow theory, and learning motivation. The questionnaire included 18 questions (Q1–Q18) measuring six dimensions (F1–F6). F1 and F2 related to authentic feeling in and outside of the cockpit. F3 and F4 determined the degree of attention and external influence when operating the simulator or game. F5 related to the sense of time when operating the simulator. F6 assessed learning motivation. A five-point Likert scale was used to score the survey results of each question; a score of 5 denoted "strongly agree" and 1 meant "strongly disagree." The comprehension questionnaire was comprised of ten questions (T1–T10) and was likewise scored based on the five-point Likert scale; a score of 5 denoted "strongly understand" and 1 meant "completely do not understand." T1 through T4 assessed comprehension of basic aircraft component functions; T5 through T10 assessed comprehension of basic control principles. Finally, we calculated the scores of the questionnaires and evaluated the learning effects.

4 Results

4.1 Comprehension Assessment

Each dataset of two groups was collected from different students. Thus, they were uncorrelated and mutually independent; therefore, the independent sample *t*-test was suitable for analyzing the results obtained from the questionnaires. First, we calculated the mean values of the questionnaire results, as shown in Table 1; a score of 1 denoted "thorough incomprehension" and a 5 meant "thorough comprehension." The pre-test column outlined the baseline comprehension test results; the post-test column outlined comprehension results after completion of the pilot study. The preliminary test results indicated that the mean values in the pre-test column were less than 3.0 and that there was little difference between Groups 1 and 2. That is, students' initial comprehension levels in basic flight control principles were consistent across the two groups; their comprehension was insufficient for both control components and principles. On the other hand, the mean values in the post-test column were all higher than 3.0, indicating that comprehension in control principles had noticeably improved. Meanwhile, the mean values for each question were higher for Group 2 than for Group 1, which suggests that the use of ARFLY was more effective than GAMEFLY in assisting student learning.

We then performed Levene's test on the equality of variances using the data obtained in these two teaching scenarios. If the variance of the two sub-populations was equal, the independent sample t-test employed the pooled variance t-test [16], whereas a separate variance t-test was appropriate if this was not the case.

The test results ($p > 0.05$) from the pre-test indicated that comprehension of control principles did not significantly differ between the two groups. The post-test results of component comprehension, specifically of the aircraft elevator (T1, $t = -2.159$, $p < 0.05$), aileron (T2, $t = -2.378$, $p < 0.05$), and yaw rudder (T3, $t = -2.744$, $p < 0.05$), suggested that Group 2 achieved better comprehension than Group 2. Meanwhile, comprehension of control principles, specifically on transitioning from actual to command indication states (T7, $t = -2.612$, $p < 0.05$), overshooting (T8, $t = -4.330$, $p < 0.01$), reverse overshooting (T9, $t = -3.546$, $p < 0.01$), and operational approaching (T10, $t = -4.022$, $p < 0.01$), was significantly better for Group 2 than for Group 1. On the whole, the comprehension level of Group 2, which used ARFLY, was significantly higher than that of Group 1, which employed conventional learning methods and GAMEFLY.

Table 1. Pre- and post-test results comparison for groups 1 and 2 based on independent-sample t-test for comprehension of basic flight control principles

		Pre-test				Post-test			
No.	Group	Mean	SD	t	Sig. (2-tailed)	Mean	SD	t	Sig. (2-tailed)
T1	1	2.50	0.522	0.394	0.698	4.00	0.426	−2.159	0.042
	2	2.42	0.515			4.42	0.515		
T2	1	2.58	0.515	0.000	1.000	3.92	0.515	−2.378	0.026
	2	2.58	0.515			4.42	0.515		
T3	1	2.58	0.793	0.000	1.000	3.92	0.515	−2.755	0.012
	2	2.58	0.515			4.50	0.522		
T4	1	2.42	0.515	−1.216	0.237	4.25	0.452	−.432	0.670
	2	2.67	0.492			4.33	0.492		
T5	1	2.58	0.515	0.793	0.436	4.17	0.389	−.920	0.368
	2	2.42	0.515			4.33	0.492		
T6	1	2.33	0.492	−1.658	0.111	3.83	0.577	−1.701	0.103
	2	2.67	0.492			4.25	0.622		
T7	1	2.67	0.492	1.216	0.237	3.58	0.515	−2.612	0.016
	2	2.42	0.515			4.17	0.577		
T8	1	2.75	0.452	1.685	0.106	3.50	0.522	−4.330	0.000
	2	2.42	0.515			4.42	0.515		
T9	1	2.67	0.492	1.658	0.111	3.83	0.389	−3.546	0.002
	2	2.33	0.492			4.50	0.522		
T10	1	2.58	0.515	0.793	0.436	3.67	0.492	−4.022	0.001
	2	2.42	0.515			4.50	0.522		

4.2 Learning Experience Assessment

Using the same method described in Sect. 4.1, the mean values for students' learning experience under the two approaches were analyzed; the results are provided in Table 2. The results indicated that the mean values for Group 2 were all greater than 3.5, which were overall greater than the Group 1 values. In particular, the mean values of F1, for authentic feeling in the cockpit, were significantly greater for Group 2 than for Group 1. The mean values of F1 to F5 for Group 2 were additionally greater than those of Group 1. These results suggest that the students in Group 2 had a greater sense of immersion in the learning scenarios.

Table 2. Results comparison for groups 1 and 2 based on independent-sample T-test for learning experience

No.	Group	Mean	SD	t	Sig. (2-tailed)
F1	1	2.83	0.507	−12.800	0.000
	2	4.11	0.319		
F2	1	3.17	0.378	−2.331	0.023
	2	3.44	0.607		
F3	1	2.86	0.683	−9.035	0.000
	2	4.08	0.439		
F4	1	2.81	0.577	−9.567	0.000
	2	4.00	0.478		
F5	1	2.75	0.649	−8.542	0.000
	2	3.94	0.532		
F6	1	3.11	0.622	−2.393	0.019
	2	3.44	0.558		

Independent *t*-test samples indicated that the Group 2 students more intensely experienced the feeling of sitting in a cockpit (F1, $t = -12.800$, $p < 0.01$), and they experienced the external scenarios as more authentic (F2, $t = -2.331$, $p < 0.05$). Through the use of ARFLY, students demonstrated a higher level of attention (F3, $t = -9.035$, $P < 0.01$), were less influenced by the external environment (F3, $t = -9.035$, $P < 0.01$), experienced time passing more quickly (F5, $t = -8.542$, $p < 0.01$), and showed a greater interest in learning (F6, $t = -2.393$, $p < 0.05$). In summary, the students in Group 2 demonstrated a more authentic and impressive learning experience.

5 Discussion and Conclusions

Because the high school technical course is not included in the college entrance examination, and most teachers implement traditional lecturing as the major teaching strategy, some students are not interested in this course [17]. The unsatisfactory situation of high school general technology in China makes it difficult to gain, sustain, and stimulate students' attention and curiosity to learn [18]. As a result, the learning motivation of this course for students is insufficient. Thus, authentic learning based on new interactive techniques is required to motivate students to participate and learn in the technical course.

The principles of flight control belong to the control theory section of the general technology course (http://www.rbloc.cn/). Most flight simulators are typically more expensive. In addition, no flight simulators exist that are suitable for high school students in a technical course. Hence, most high schools adopt the traditional way of teaching. This disables the course from stimulating students' enthusiasm for the learning of flight control principles; moreover, the students are unable to sufficiently understand the related theory. To overcome this problem and address the related need, the low-cost ARFLY was developed under the guidance of authentic learning theories; its virtual 3D models replace the complex and expensive instrument panels of actual simulators while realizing all operating functions.

Most teaching-aided systems that adopt 2D interfaces rely on the well-established windows, icons, menus, pointers (WIMP) interface metaphor. AR-based user interface techniques and interaction devices are not common in education [19]. In ARFLY, traditional computers and their well-known devices and interfaces disappear from the user's point of view. A new type of AR-based user interface is introduced, enhancing immersion in learning very well. Accordingly, AR can provide a more varied interactive mode, such as with spatial interaction, command-based interaction, virtual control interaction, and physical control interaction [10]. ITS can call and display different flight missions on the virtual instrument panel without influencing the simulation scenarios. In addition, it can estimate the completion of a flight mission and assign a new one, as if directed by a real commander. ITS was independently developed, which reduces external influences and improves students' understanding of the aircraft components and control principles. The ITS in ARFLY uses interactive technology and was specially developed to guide learning. It can reduce the heavy burden on teachers and improve learning effects. During the flight mission, a balance between the challenge and skill is made; the challenge does not exceed the student's current skill level. Therefore, students are not made to feel confused or anxious; conversely, the challenge is not so simple that it engenders boredom and interest loss [20].

Compared to GAMEFLY, ARFLY helps students to form more concrete concepts, develop a greater understanding of aircraft component functions and control principles, and, in particular, more closely grasp the abstract concepts of overshooting, reverse overshooting, and command transacting. A conventional flight simulation game typically displays the flight mission and simulation state simultaneously in menu form. This approach lacks a coherent learning system. When assigning a flight mission, it first blocks or mixes the simulation scenario and then explains the mission through text, audio, images, or video. From that point, the user can finally re-enter the simulation scenario. This easily distracts the user and does not match an actual flight experience, whereas ARFLY displays the information via AR technology. AR gives ITS a natural interactive environment and does not influence flight simulation effects when guiding the learning. Meanwhile, ITS can additionally increase the output of information, such as simultaneously displaying a human-presented explanation video and real-time flight state. With this intelligent-system guided learning, students can obtain task information at any time by watching the instrument panel; the simulation system and ITS can synchronize the work, which entirely fulfills the natural interactive mode. With minimal interference and a strong authentic feeling, students will be prompted to have enhanced attention, greater learning effects, and stronger learning motivations.

Acknowledgements. This research was supported by the National Natural Science Foundation of China under Grant No. 11664036.

References

1. Azuma, R.T.: A survey of augmented reality. Presence Teleoperators Virtual Environ. **6**(4), 355–385 (1997)
2. Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., MacIntyre, B.: Recent advances in augmented reality. IEEE Comput. Graph. Appl. **21**(6), 34–47 (2001)
3. Billinghurst, M., Duenser, A.: Augmented reality in the classroom. Computer **45**(7), 56–63 (2012)
4. Dalgarno, B., Lee, M.J.W.: What are the learning affordances of 3-D virtual environments? Br. J. Educ. Technol. **41**(1), 10–32 (2010)
5. Di Serio, A., Ibáñez, M.B., Kloos, C.D.: Impact of an augmented reality system on students' motivation for a visual art course. Comput. Educ. **68**, 586–596 (2013)
6. Dunleavy, M., Dede, C., Mitchell, R.: Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. J. Sci. Educ. Technol. **18**(1), 7–22 (2009)
7. Neumann, U., Majoros, A.: Cognitive, performance, and systems issues for augmented reality applications in manufacturing and maintenance. In: 1998 IEEE Proceedings Virtual Reality Annual International Symposium, March 1998, pp. 4–11. IEEE (1998)
8. Nee, A.Y.C., Ong, S.K., Chryssolouris, G., Mourtzis, D.: Augmented reality applications in design and manufacturing. CIRP Ann. Manuf. Technol. **61**(2), 657–679 (2012)
9. Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., Ivkovic, M.: Augmented reality technologies, systems and applications. Multimed. Tools Appl. **51**(1), 341–377 (2011)
10. Broll, W., Lindt, I., Ohlenburg, J., Herbst, I., Wittkamper, M., Novotny, T.: An infrastructure for realizing custom-tailored augmented reality user interfaces. IEEE Trans. Vis. Comput. Graph. **11**(6), 722–733 (2005)
11. Sutherland, I.E.: Computer displays. Sci. Am. **222**(6), 57–81 (1970)
12. Yavrucuk, I., Kubali, E., Tarimci, O.: A low cost flight simulator using virtual reality tools. IEEE Aerosp. Electron. Syst. Mag. **26**(4), 10–14 (2011)
13. Psotka, J., Massey, L.D., Mutter, S.A.: Intelligent Tutoring Systems: Lessons Learned. Psychology Press, Hove (1988)
14. Schiaffino, S., Garcia, P., Amandi, A.: eTeacher: providing personalized assistance to e-learning students. Comput. Educ. **51**(4), 1744–1754 (2008)
15. Keleş, A., Ocak, R., Keleş, A., Gülcü, A.: ZOSMAT: web-based intelligent tutoring system for teaching–learning process. Exp. Syst. Appl. **36**(2), 1229–1239 (2009)
16. Carroll, R.J., Schneider, H.: A note on Levene's tests for equality of variances. Stat. Probab. Lett. **3**(4), 191–194 (1985)
17. Davey, G., De Lian, C., Higgins, L.: The university entrance examination system in China. J. Furth. High. Educ. **31**(4), 385–396 (2007)
18. Jiang, S.: Analysis of general technology course teaching and subject construction in senior high schools (article written in Chinese). Educ. Teach. Res. **29**(3), 112–114 (2014)
19. Kaufmann, H., Schmalstieg, D.: Mathematics and geometry education with collaborative augmented reality. Comput. Graph. **27**(3), 339–345 (2003)
20. Chan, T.S., Ahern, T.C.: Targeting motivation: adapting flow theory to instructional design. J. Educ. Comput. Res. **21**(2), 151–163 (1999)