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A VR-based Industrial Robot Platform for Interactive Teaching Specialized Courses of Mechatronic Engineering

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Abstract. The primary objective of Industry 4.0 is to establish seamless connections between the physical and digital domains. Virtual Reality technology is widely acknowledged as a revolutionary advancement that offers significant technical assistance to many different fields including industry, agriculture and individuals. Since its inception, VR-based education has not gone out of that trend. The paper outlines a methodology for developing virtual interactive applications for the purpose of teaching Mechatronics. Unity software is utilized for creating a three-dimensional virtual robot and its corresponding environment. Subsequently, a user-friendly interface for controlling a robot is constructed. Finally, a lesson plan was developed for the virtual interactive teaching approach in the industrial robot course for the undergraduate Mechatronics Engineering program. The integration of a quantitative evaluation approach, along with the subsequent self-assessment conducted by students upon completion of the module, has unequivocally shown enhancements and efficacy across several competencies with increases ranging from 85 to 92%. The utilization of virtual reality and interactive learning within virtual environments, together with the guidance of instructors, has significantly improved the learning experience and problem-solving abilities of engineering and technology students, enabling them to fulfill the required performance criteria.

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1. Introduction

The fundamental aim of Industry 4.0 is to forge integrations between the physical and digital realms (Dang & Bui, 2023a; Dang et al., 2023). Virtual Reality (VR) technology, which is widely recognized as a transformative advancement, provides substantial technical support to a wide range of sectors, such as industry, agriculture and individuals (Guo et al., 2020). Practice sessions are critical components of engineering and technology education as they facilitate students' understanding of theoretical concepts. Practical experience is an indispensable means through which a learner can cultivate their technical expertise (Pérez et al., 2022). Web-based and virtual laboratories have the capacity to captivate students while providing them with an experience comparable to using lab equipment (Gil et al., 2017). Conversely, conventional instructional approaches demonstrate a lack of interactivity and neglect to actively engage students in the learning processes, thus indirectly impacting their effectiveness (Garduño et al., 2021). VR has the capacity to revolutionize the pedagogical process by facilitating comprehension of intricate subjects and imparting profound insights, as well as challenging and pertinent information. With the help of VR, even philosophical theories can be brought to life (Shaukat, 2023).

Advanced technology learning will dominate classrooms in the twenty-first century, with VR technology enhancing student engagement and learning. The VR experience will motivate an entire generation of intelligent young students who are prepared to innovate and alter the course of history (Shaukat, 2023). Additionally, VR facilitates universal access to affordable human knowledge. The following characteristics should define a VR-based education application: immersion, usability, significance, adaptability, and measurability (Mikropoulos et al., 1998; Wang et al., 2021). He (2023) highlighted that physical education is progressively being integrated into the metaverse to overcome the imposed limitations of practical places. The flexible combination between the training and education with computer-assisted created inevitable progressions such as VR-based education. Panrelidis (2009) proposed a ten-step model for VR-based training and education courses. The components of VR-based education are as follows: virtual laboratories, tools and learning environments; distance education; and STEM education (Panrelidis, 2009; Shaukat, 2023). Reeves and Crippen (2021) examined the use of virtual laboratories in engineering and science courses for undergraduates. Therefore, additional research is necessary to examine the influence of personal attributes and history on the observed variability in V-Lab experiences (Dang & Bui, 2023b). Furthermore, it is imperative to analyze the potential of design to promote social learning in established instructional frameworks through the integration of instructors and students. Engineering students benefit from virtual laboratories, simulation control assessments, and remote physics experiments as part of VR's educational initiatives. By enabling interactive operation of the virtual model, both the instructor and the learner can observe the tangible development of the project as well as the advancement of architectural tasks that are intrinsic to it (Solmaz & Gerven, 2020). Hence, incorporating VR technology into the teaching process introduces a novel paradigm to the field of engineering education (Duning, 1987).

The paper proposes the process of designing virtual interactive programs in teaching Mechatronics Engineering programs. Then, Unity software is used for 3D virtual robot and its environment. Next, an interactive robot control interface is built. Finally, virtual interactive teaching method lesson plan for IR courses in the Mechatronics Engineering program at undergraduate level. The quantitative assessment method combined with the results of student self-assessment at the end of the module demonstrated improvement and effectiveness in many skills including teamwork, problem-solving ability, thinking ability, ability to acquire knowledge, ability to concentrate, ability to be confident, ability to interact increased from 85 to 92%. The VR application major has demonstrated its ability to enhance the cognitive and application abilities of students majoring in technology, meeting the output standards of the specialized courses of Mechatronics Engineering.

2. Literature Review

Interaction in education has been the subject of numerous studies and classifications, as well as numerous debates concerning these classifications. Consider the debate between Pittman (1987) as an illustration. Students cannot learn in a classroom without some kind of interaction between teachers and students. Nevertheless, learner-instructor interaction (LII), learner-content interaction (LCI), and learner-learner interaction (LLI) are the three main forms of interaction in education. In Moore's Interaction Framework, LII refers to the dynamic between the instructor and the learner. Motivation, instruction and evaluation are all components. However, students expressed that they encountered difficulties when acquiring verbal communication skills, specifically in blended environments where LII interaction takes place. In a blended learning environment, instructors assume substantial responsibilities in LII pertaining to verbal communication instruction and learning (Ramalingam, 2023). In online inquiry, the effectiveness of LCI is contingent on the degree to which students' cognitive presence can be encouraged. The objective of this research was to determine how scaffolding support improves cognitive presence during the online LCI's process (Igoni & Oluwuo, 2023; Mamun & Lawrie, 2023). LCI and LLI are predicated on facilitating discussions among students regarding the material's content as a means of self-education and self-interaction (Igoni & Oluwuo, 2023).

The researchers were particularly interested in LCI for the purposes of this investigation. The effectiveness and efficiency of contemporary blended learning systems are heavily reliant on interaction. LCI is the primary factor that significantly influences the achievement of desired learning outcomes (Kumar et al., 2021). Lanier et al. (2022) investigated and pointed out that instructors should curate and present content in a way that engages students to foster good LCI. Because the intellectual LCI stimulates the learner's understanding, the learners improve their ability to interact and solve real-life problems. A sizable percentage of adults also engage in self-directed learning (Confessore Confessore, 1992;

Murugesan & Inrahim, 2022). Creating an effective LCI will also facilitate the application of a crucial principle in education: cultivating enduring abilities for lifetime learning. Formulating and implementing higher education policies can enhance the development of inclusive and comprehensive frameworks that align with the requirements and goals of higher education stakeholders (Cronholm, 2022; Tamez, 2014).

As for teaching at the college and university level, virtual worlds facilitate many forms of interactions, either between users and virtual content or among the users themselves, by providing the appropriate environment. Virtual worlds refer to 2D or 3D computer-generated environments depicting aspects of the real world or fictional landscapes (Mikropoulos et al., 1998; Pantelidis, 2009; Shaukat, 2023). Specifically, users can engage in various interactions with the content of the virtual world and other users (He, 2023; Mayne & Green, 2020; Reeves & Crippen., 2021). These interactions include creating objects, manipulating them, adjusting the terrain and engaging in synchronous or asynchronous chat. Chats can be conducted verbally through voice or text chat, or through visual interactions using avatar gestures and other forms of visual communication within the virtual world (Dinis et al., 2017). Students gain a comprehensive knowledge of the mechanical, electrical, electronics, information technology and technology education employed in virtual simulations. Learners will develop awareness through interactions and actively engage in learning activities aimed at developing innovative engineering technicians. Xie et al. (2023) highlighted that learners' capacity to exert influence, modify, and augment the content of the virtual environment in which they learn enables them to construct cognitive strategies and actively engage with the topics they are studying. Consequently, learning becomes autonomous and focused on the individual student (Tamez, 2014), while educators assume the responsibilities of designing, facilitating and guiding activities that aim to actively include students (Cronholm, 2022).

3. Explanatory Case Study

First, traditional teaching methods exhibit a deficiency in interactive elements and fail to actively involve learners in the educational procedures, which consequently undermines their efficacy. VR possesses the potential to fundamentally transform the pedagogical process through its ability to enhance understanding of complex topics, convey profound insights and present challenging and pertinent information.

Second, concerning the degree to which students engage with the material being taught, educators frequently encounter obstacles. Utilizing interaction in the virtual world, which has been adapted to satisfy educational requirements, to increase LCI and motivation is the central argument of this paper. More interactivity within the virtual environment enhances learners' motivation to acquire knowledge and facilitates the attainment of learning objectives. In this research endeavor, the authors enable concurrent student engagement with educational materials in both the physical classroom and the virtual environment, while also identifying stimuli that may be associated with the content being studied. Consequently, the hypothesis of this study is that if interactive learning content is implemented at an advanced level, it will generate elevated levels of learner motivation, positive interaction with learning content and superior learning outcomes.

The authors designed a method for developing virtual interactive programs for use in the instruction of Mechatronics Engineering programs. The quantitative evaluation approach, in conjunction with student self-assessment outcomes, is implemented after the module's conclusion. The implementation of interactive learning in virtual environments, combined with VR, has significantly improved the students' problem-solving abilities and the learning experiences of engineering and technology students. This was achieved under the guidance of instructors, ultimately assisting the students in meeting the required performance standards.

3.1 The Design of Virtual Interactive Program (VIP) Process

The research was conducted with two types of control and experimental classes when studying IR course at Thai Nguyen University of Industry, Vietnam. The number of students in the sample classes was 40 students taught by the specialist lecturers like MEng. Thi-Thanh-Thuy Tran and MEng. Trung-Cong Do. There are also experienced educational experts and lecturers with pedagogical skills.

The design of VIP process included the following steps as shown in Figure 1:

Step 1 - Select the VIP's object to design a model: Build a virtual interaction model of an IR arm picking up objects, full virtual interaction via Oclus Go glasses and virtual interaction via phone.

Step 2 - Choose a suitable tool to design VIP: Use a computer with Unity software and other support installed software.

Step 3 - Choose suitable software to design VIP: Choose Unity software to design and draw models, which supports C++ software programs.

Step 4 - Design a VIP scenario on the model: Firstly, draw the details of the robot arm. Then, control the robot arm rotation angles with two modes: automatic via sensor system and control by hand with mouse. Next, control picking and dropping objects with the robot arm with two modes: automatic touch point and manual mouse control. Finally, control the robot arm to interact with the version on glasses and on the phone.

Step 5 - Construct a VIP model: Firstly, run Unity software. Then, design and draw models according to scenario Step 4. Next, save the file you just drew.

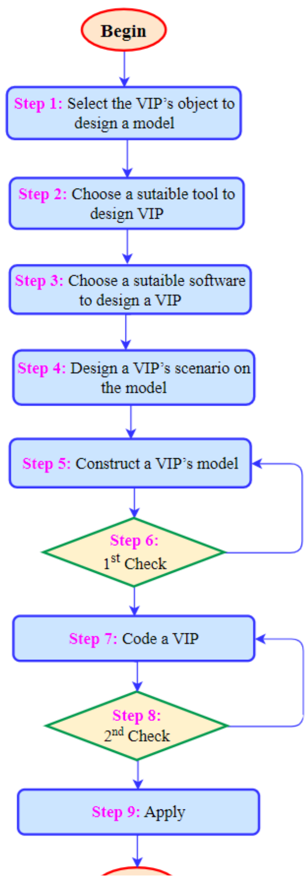


Figure 1: The flowchart of a VIP design process.

Step 6 - 1st Check: Test to run the 3D model designed by Unity and if meeting the requirements in accordance with the teaching content, continue to move to Step 7. If you see inappropriate joints or joint movements, go back to Step 5.

Step 7 - Code VIP: Use C++ programming language, program and control the robot arm program according to Step 4's requirements.

Step 8 - 2nd Check: When checking that the VIP has been programmed, if there is an error, go back to Step 6 to edit. When the running program is complete, move on to Step 9.

Step 9 - Apply: Complete the model to run the simulation independently and include it in the lesson plan. Finally, finish the VIP design process.

3.2. Design Specialized Lessons of IR Course Based VIP

Based on the VIP design process, the researchers chose the specialized courses of Mechatronics Engineering such as an IR course with three sample lessons as follows:

Lesson 1: Analog control based on sample displacement. The program exercises control over the complete IR arm through the operational mechanism of the displacement robot arm joints. By acquiring a comprehensive understanding of controlling displacement mechanisms, individuals can logically and rationally incorporate the entire body of knowledge pertaining to the control of IR arms.

Lesson 2: Inverse kinematics problem with GVS and torsional displacement rules. The kinematic problem is inverse to the rule of torsional displacement in general and the kinematic problem with teachers can easily control the moving mechanism at an angle greater than 1500° through the designed virtual interactive teaching method. on smartphones, using semi-immersive virtual interactive teaching methods.

Lesson 3: Multi-axis robot numerical control system. The problem of numerical control of multi-axis robots can be controlled by the assimilation in the operation of the robot arm, in which the development of inter-mechanical control will affect the operating mechanism of the robot arm as well as the power properties. Structural strength includes coordination between control systems and mechanical power in controlling heavy lifting. On the other hand, this multi-axis control system also has a decisive influence on the continuity in axis system control designed through a full VIP using Oclus Go glasses.

The snapshots in Figure 2 present the VIP-based sample lessons in the IR course.

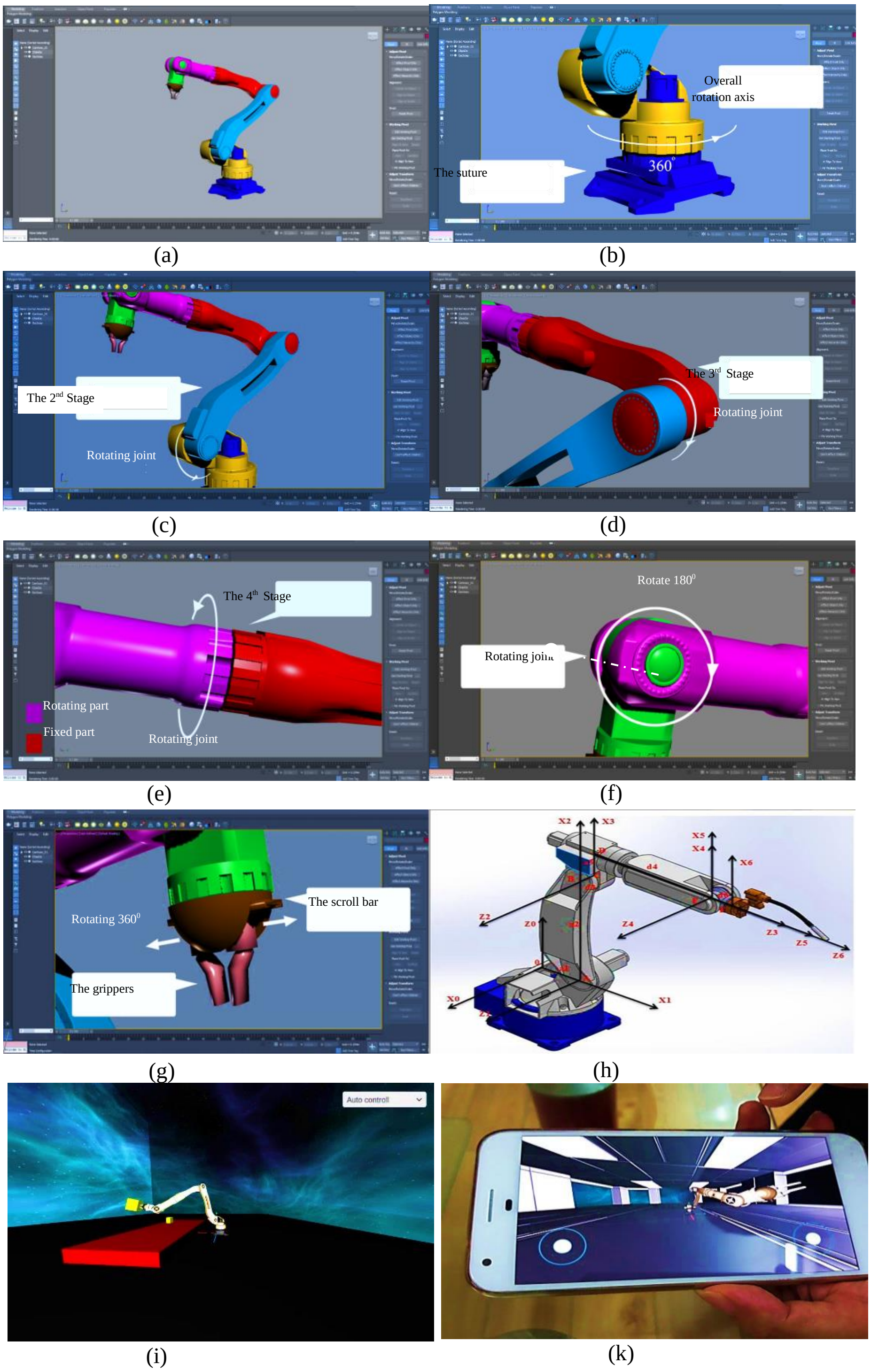


Figure 2: The specialized lessons of IR course based VIP with (a): constructing the 3D model; (b): the suture base; (c): the 2nd stage; (d): the 3rd stage; (e): the 4th stage; (f): the ability of rotating 1800; (g): the gripper; (h): calculating the D-H matrix; (i): VIP-based IR teaching; and (k): VIP-based lesson connecting to mobile phone

In Figure 2a, the students completely construct the 3D model of the IR under lecturer monitoring. Then, according to Step 6, they tested the 3D model designed by Unity software. Next, they checked the requirements in accordance with the teaching content of three VIP-based lessons (see from Figure 2b to Fig 2g). Figure

2h helped student to define the D-H coordinate system of the IR. Hence, the robot control programming code ensured the robot's operation, in Figure 2i. Finally, Figure 2k shows the interface of a VR's lesson via mobile phone.

3.3. Results and Discussion

3.3.1 Designing the process of organizing virtual interactive teaching

In Figure 3, the teaching organization process includes three phases as follows:

Phase 1: is the preparation phase to develop an effective virtual interactive classroom organizational structure in which: During the preparation stage, three steps need to be carried out. Step 1: design lectures and VIP-based teaching; Step 2: design VIP's teaching activities; and Step 3: design the VIP's teaching environment.

Phase 2: uses virtual interactive teaching based on Phase 1. However, this phase is heavily influenced by the intuition of teachers and learners. Then, the virtual interaction device interaction is objectively affected in the experimental practice. During this stage, three steps need to be carried out. Step 1: theoretical lectures are conducted experimentally; Step 2: lecturers guide students through the VIP, instructing them on how to control the sensor system manually as well as by using the mode buttons in the VIP; Step 3: students interact with the VIP, students can use Oclus Go glasses for immersive VIP classes and use phones for semi-immersive VIP classes and start using the VIP.

Phase 3 is the evaluation and improvement. The evaluation and improvement phase are applied to teaching and learning activities according to the following steps: Step 1: evaluate teaching and learning activities; Step 2: evaluate the learning process; and Step 3: evaluate the VIP teaching methods. During this stage, qualitative and quantitative assessment methods were used based on students' learning results after the experiment, collecting students' opinions after studying the experiment, and getting expert opinions.

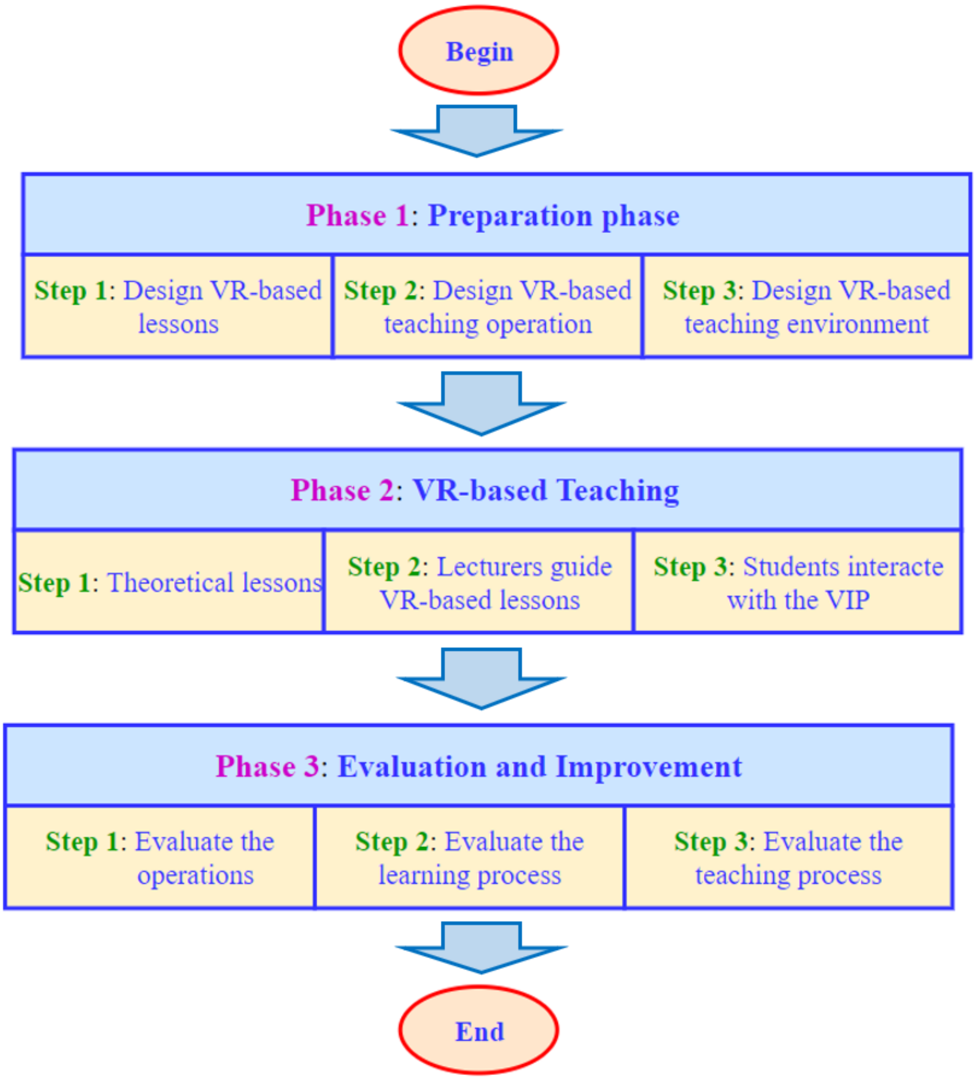


Figure 3: The process of organizing virtual interactive teaching

3.3.2 Qualitative and quantitative assessment results

After attending the VIP-based IR course and conventional IR course without VIP, qualitative assessment results were obtained from the opinions and comments of teachers participating in observing lessons for three VIP-based teaching lessons in the two experimental and control classes (see Figure 4). Processing experimental results: Mathematical statistical data obtained during the experiment were processed using SPSS and Microsoft Excel software.

Based on feedback received after attending the VIP-based course, the researchers came to the following conclusions: The implementation of suitable stimulation techniques unquestionably increases students' interest in learning; Instructional hours are vibrant; a considerable number of students engage in active and enthusiastic study during lesson construction; and voices have a discernible impact on student engagement (see Figure 5).

Figure 4: Mechatronics classes 1 and 2 attend VIP-based IR course

Figure 5: Lecturer and education experts attend VIP-based IR course.

The frequency of teacher lecturers in the classroom is diminished, and in their place, students engage in active self-help activities. Classes become natural and pleasant. The rapport between educators and learners is enhanced, as instructors can readily discern the cognitive development and academic aptitude of every student. Conversely, proficient students are afforded the opportunity to demonstrate their extensive practical expertise.

Table 1: The score rating

The table of score conversion								
A+	A	B+	B	C+	C	D+	D	F
9.5-10	8.5-9.4	8.0-8.4	7.0-7.9	6.5-6.9	6.0-6.4	5.5-5.9	5.0-5.4	<=4.9
9.75	8.45	8.2	7.45	6.7	6.2	5.7	5.2	2.45

Table 2: The overall academic score

Content	How to calculate the overall academic score
1. Learning process score	Learning process score (LPS) = (The first test score + The second test score + The third test score)/3
2. Overall academic score	Overall academic Score (OAS) = 30%* Learning process score +70%* Course completion score (CCS)

By adhering to the selected virtual interaction, educators are can allocate additional time and energy toward preparation and self-improvement to enhance their professional credentials and learn innovative teaching approaches. Furthermore, to enhance and demonstrate the improvement and effectiveness of the VIP-based curriculum, the researchers conducted the quantitative assessment. Students' course completion assessment scores are shown in Tables. 1 and 2. After completing the VIP-based teaching of IR, the summary chart of the control class (CC's) test scores is shown in Figure 6 and the experimental class (EC) is shown in Figure 7, respectively.

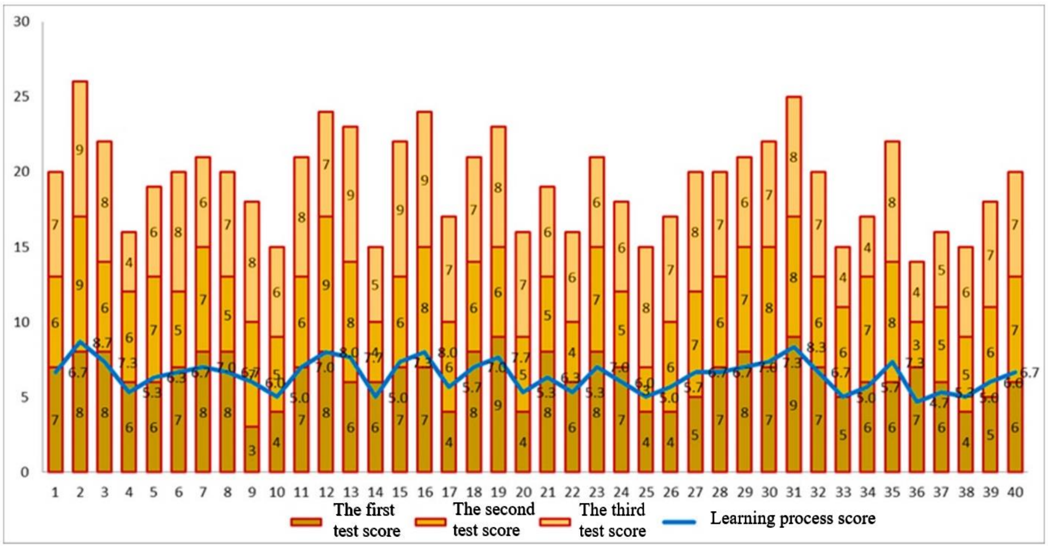


Figure 6: The summary chart of CC's test scores.

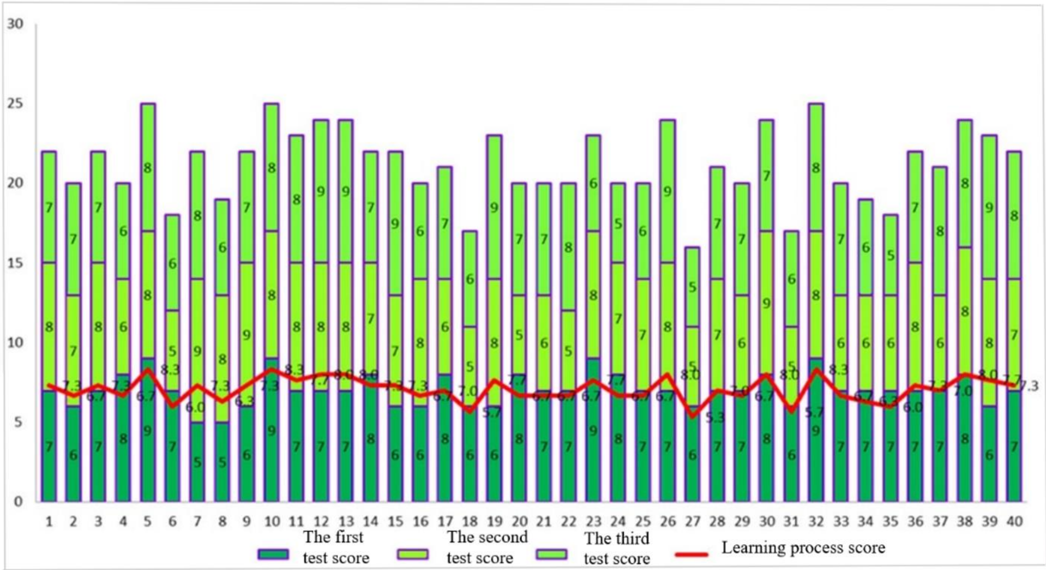
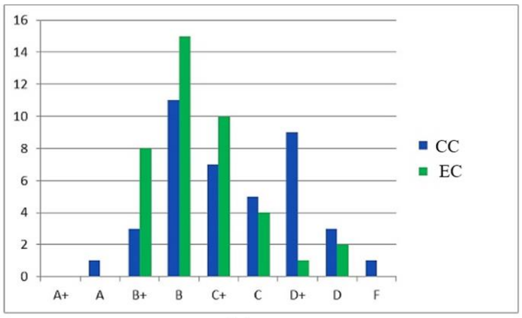


Figure 7. The summary chart of EC's test scores

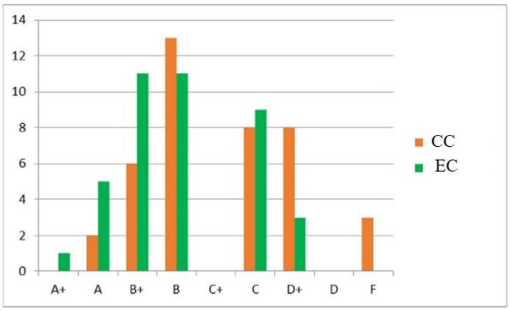
Finally, the comparison process between the learning process score (LPS) and course completion score (CCS) of the two classes (CC, EC) was conducted to find differences as shown in Figure 8.

Score rate		CC		EC	
		LPS	CCS	LPS	CCS
A+	9.5-10	0	0	0	1
A	8.5-9.4	1	2	0	5
B+	8.0-8.4	3	6	8	11
B	7.0-7.9	11	13	15	11
C+	6.5-6.9	7	0	10	0
C	6.0-6.4	5	8	4	9
D+	5.5-5.9	9	8	1	3
D	5.0-5.4	3	0	2	0
F	<=4.9	1	3	0	0

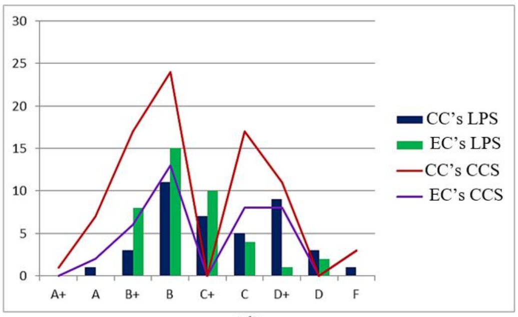
(a)



(b)



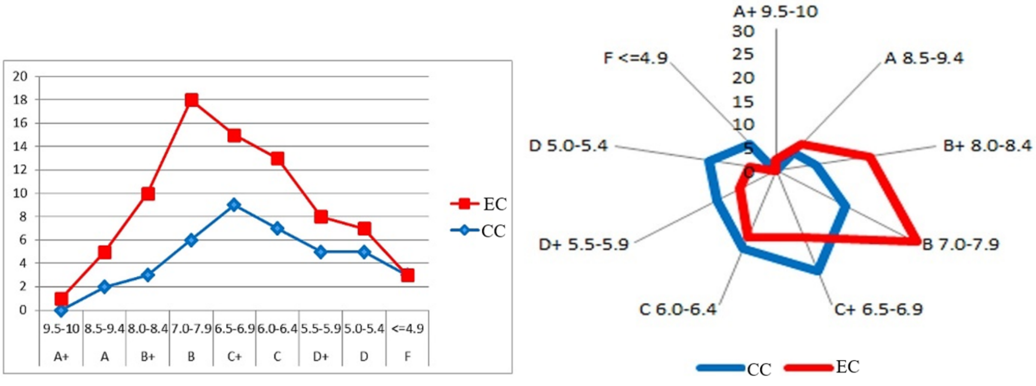
(c)



(d)

Figure 8: The comparison between the control and experimental classes with (a): Score rating of two classes, (b): The comparison chart of LPS, (c): The comparison chart of completion score, and (d): The comparison chart of overall learning process

In Figure 8a, both LPS and CCS of the two classes (CC, EC) were collected. Then, the comparison chart is reflected in Figures 8b to 8d to show the better quality of EC than CC based on the VIP IR course.



(a) (b)

Figure 9: The characteristic curve of students' score with (a): The frequency curve converges of the student's scores X_i and (b): The popular Radar line of the student's scores X_i

Moreover, based on the obtained scores, the researchers performed the frequency curve converges of the student's scores X_i in Figure 9a and the popular Radar line of the student's scores X_i in Figure 9b. Hence, the characteristic curve of students' score in the EC had a much higher rating than that of students in the CC without VIP.

Table 3: Comparison table of statistical parameters

Class	N	$\bar{X}$	δ^2	δ	γ
CC	40	6.3	2.1	1.45	23
EC	40	7.2	1.1	1.03	14

In particular, the VIP-based courses led to students obtaining outstanding scores in EC. To apply the formula to calculate variance $\bar{X}$, standard deviation δ, squared standard deviation δ^2 and coefficient of variation γ (Kawai & Wittenberg, 2017) for the CC and EC, authors obtain the result is the following Table 3.

Firstly, use student's rule yielded:

$$t = \frac{\bar{X}_{EC} - \bar{X}_{CC}}{\sqrt{\frac{\delta^2_{EC}}{N_{EC}} + \frac{\delta^2_{CC}}{N_{CC}}}} = \frac{7.2 - 6.3}{\sqrt{\frac{1.1 + 2.1}{40}}} = 3.2, \quad (1)$$

where δ^2_{EC} is squared standard deviation of EC's score and δ^2_{CC} is squared standard deviation of CC's score, respectively; $\bar{X}_{EC}$ is average score of EC and $\bar{X}_{CC}$ is average score of CC, respectively.

Then, choosing the level of significance $\alpha = 0.05$ in the student table. Next, calculate the factor k in the student table in (2):

$$k = N_{EC} + N_{CC} - 2 = 40 + 40 - 2 = 78. \quad (2)$$

As for $k = 78$, looking up the student relationship table, it yields $t_{student} = 2$.

The improvement in the overall academic score of VIP-based courses was better than conventional courses.
Using Fisher's rule to calculate the F coefficient:

$$F = \frac{\delta^2_{EC}}{\delta^2_{CC}} = \frac{1.1}{2.1} = 0.5, \quad (3)$$

Because the coefficient $F < 1$ proves that the scores of the EC and CC are stably distributed around the value $\bar{X}_i$. with a level of significance $\alpha = 0.05$, the student relationship table yields $F_{student} = 1.66$. Because $F_{student} > F$, the researchers showed that the difference between δ^2_{EC} and δ^2_{CC} is acceptable.

Based on Eqs. (1) to (3), in the two frequency graphs in Figure 9, the researchers illustrated that the number of students scoring Xi or higher in the EC is always higher than the CC. Hence, the VIP-based course actually supports and helps students in studying and practicing specialized subjects.
Summing up, the researchers drew the following conclusions:

- The cognitive positivity of students in the EC was aroused and clearly demonstrated. Lively, convenient hours attract attention and create constructive debate with the virtual interaction of lectures.
- The quality of mastery, application of knowledge and intellectual capacity of students in the EC is higher than that of CC, which is shown by the higher average score of the EC in both lessons than the CC.
- The ability to reason and express the VIP-based course in virtual interactive language and understanding of the EC is higher than the CC.

Furthermore, to evaluate the effectiveness of the selected methods for the course under consideration, in addition to conducting pedagogical experiments as above, the researchers used another research method to collect students' opinions after class to evaluate student satisfaction, the development of student skills, self-study skills, teamwork skills. At the same time the researchers used expert evaluations to confirm the effectiveness results of VIP-based teaching methods.

Table 4: Evaluation form on student satisfaction

After studying the VIP-based Industrial Robotics module	Totally agree	Agree	Partially agree	Disagree	Totally disagree
1. Enjoy	15	20	4	1	0
2. Beautiful	20	16	3	0	1
3. Attractive	23	12	4	1	0
4. Intuitive	16	21	3	0	0
5. In good spirits	17	20	2	1	0
6. Easy to understand	14	19	6	1	0

After completing the class, students surveyed felt 100% interested, the lecture was attractive 77.2%, the lecture was easy to understand 72.3%, the lecture was intuitive 90.9%, the lecture was lively 77.2 %, in Table 4.

In Table 5, the increased skills that students have after class were: 91% critical thinking, 98% observation, 85% memorization, 81% analysis and solution skills, thinking skills logic 78%, dynamic 93%, creative thinking 93%. For the skills that students self-assessed would increase, the highest level of agreement is 63% of opinions completely agreeing about increased dynamic ability and 68% of opinions agreeing with the ability to move. Creative thinking will increase if students continue to learn VIP-based courses. Table 6 illustrates the student's feeling about the VIP-based IR such as follows: 75% exciting, and 85% interesting. These results prove its attractiveness and create a happy and comfortable atmosphere in student learning. Moreover, there were neutral or silent opinions. Hence, positive student feelings will support their learning abilities. Futhermore, Table 7 also presents the VRs necessary for the IR course with the following indices: 52.5% understand; 62.5% practice; 95% observe and analyze; 87.5 % understand motion and properties. Finally, the VR-based IR course achieved positive results in training combined with practice in specialized technical modules at universities and colleges.

Table 5: Evaluation of student skill improvement after studying VIP-based IR course

Skills are increased after after studying the VIP-based Industrial Robotics course	Totally agree	Agree	Partially agree	Disagree	Totally disagree
1. Critical thinking	10	27	2	1	0
2. Observation	14	25	1	0	0
3. Memorization	12	22	5	0	1
4. Analysis and problem solving	15	21	3	1	0
5. Logical thinking	11	20	5	3	1
6. Dynamic	25	12	2	1	0
7. Creative thinking	12	20	6	1	2

Table 6: Evaluation of student's feeling after studying VIP-based IR course.

Student's feeling after studying VIP-based IR in the comparison with VIP without IR	Opinion	Percents
Exciting	30	75.0%
Interesting	34	85.0%
Undifferentiated	0	0.0%
Silent	0	0.0%

Table 7: Evaluation of student: VR's necessary for IR course.

VR's support to IR course	Opinion	· Percents
Understand the IR control's algorithm	21	52.5%
Practical practice based VR	25	62.5%
Observe and analyze activities	38	95.0%
Motion sequences and properties	35	87.5%

4. Conclusion

The integration of VR and VIP in virtual environments, under the supervision of instructors, substantially enhanced engineering and technology students' problem-solving skills and learning experiences, thereby facilitating the attainment of the prescribed performance standards. Evaluating the effectiveness of using VIP-based teaching for the IR course, 83.3% of the experts agreed that VIP increased teamwork ability; 83.4% agreed that it increased problem-solving ability; 85% said that it increased thinking ability; 83.3% said that it increased the ability to acquire knowledge; 80% stated that it increased the ability to concentrate; 79.9% said that self-control increased. In terms of robot control, 83.4% said it increased the ability to interact with teachers; 90% said that increased the ability to interact with digital control devices. From the results of expert evaluation, we can state that VIP-based classes are effective for the IR course, with increased learning skills such as increased teamwork ability, increased thinking ability to acquire knowledge, increased problem-solving ability and increased logical thinking ability. These are necessary skills for development not only for acquiring knowledge of a difficult subject but can be used in acquiring knowledge of any subject.

5. Acknowledgment

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6. References

Confessore, G., & Confessore, S. (1992). *Guideposts to self-directed learning, expert commentary on essential concepts*. Organization Design and Development Inc.

Cronholm, S. (2022). Lifelong learning: Principles for designing university education. *Journal of Information Technology Education: Research, 20*, 35-60. https://doi.org/10.28945/4686

Dang, T. V., & Bui, N. T. (2023a). Multi-scale fully convolutional network-based semantic segmentation for mobile robot navigation. *Electronics, 12*(3), 533. https://doi.org/10.3390/electronics12030533

Dang, T. V., Bui, N. T. (2023b). Obstacle avoidance strategy for mobile robot based on monocular camera. *Electronics, 12*(8), 1932. https://doi.org/10.3390/electronics12081932

Dang, T.-V., Tran, D-M-C., & Tan, P. X. (2023). IRDC-Net: Lightweight semantic segmentation network based on monocular camera for mobile robot navigation. *Sensors, 23*(15), 6907. https://doi.org/10.3390/s23156907

Dinis, F. M., Guimarães, A. S., Carvalho, B. R., Martins, J. P. P. (2017). An immersive virtual reality interface for civil engineering dissemination amongst pre-university students. *4th Experiment at International Conference: Online Experimentation*.

Duning, B. S. (1987). Independent study in higher education: A captive of legendary resilience? *American Journal of Distance Education, 1*(1), 37-46. https://doi.org/10.1080/08923648709526571

Garduño, H. A. S., Martínez, M. I. E., & Castro, M. P. (2021). Impact of virtual reality on student motivation in a high school science course. *Applied Science, 11*(20), 9516. https://doi.org/10.3390/app11209516

Gil, L. R., García-Zubia, J., Orduña, P., & López-de-Ipiña, D. (2017). Towards new multiplatform hybrid online laboratory models. *IEEE Transactions Learning Technologies, 10*, 318-330.

Guo, Z., Zhou, D., Zhou, Q., Zhang, X., Geng, J., Zeng, S., Lv, C., & Hao, A. (2020). Applications of virtual reality in maintenance during the industrial product life cycle: a systematic review. *Journal of Manufacturing Systems, 56*, 525-538. https://doi.org/10.1016/j.jmsy.2020.07.007

He, X. (2023). A conceptual exploration: Incorporating physical education with metaverse. *International Journal of Education and Literacy Studies, 11*(4), 325-331. https://doi.org/10.7575/aiac.ijels.v.11n.4p.325

Igoni, C. G., & Oluwuo, S. O. (2023). Management of learner-learner and learner-content interaction in virtual synchronous learning for academic improvement in private secondary schools in Rivers State. *International Journal of Innovative Education Research, 11*(3), 193-200.

Kawai, E. T. G., & Wittenberg, M. D. (2014). Essential equations for anaesthesia. Cambridge University Press. https://doi.org/10.1017/CBO9781139565387

Kumar, P., Saxena, C., & Baber, H. (2021). Learner-content interaction in e-learning- the moderating role of perceived harm of COVID-19 in assessing the satisfaction of learners. *Smart Learning Environments, 8*(1), 1-15. https://doi.org/10.1186/s40561-021-00149-8

Lanier, K., Gurvitch, R., Carmon, A., & Kim, G-K. (2022). The Importance of interactions in online instruction: part 2: Learner-content. *Journal of Physical Education, Recreation & Dance, 93*(4), 11-16. https://doi.org/10.1080/07303084.2022.2050143

Mamun A. A., & Lawrie, G. (2023). Cognitive presence in learner–content interaction process: The role of scaffolding in online self-regulated learning environments. *Journal of Computers in Education*. https://doi.org/10.1007/s40692-023-00279-7

Mayne, R., & Green, H. (2020). Virtual reality for teaching and learning in crime scene investigation. *Science & Justice, 60*, 466-472. https://doi.org/10.1016/j.scijus.2020.07.006

Mikropoulos, T., Chalkidis, A., Katsikis, A., & Emvalotis, A. (1998). Students' attitudes towards educational virtual environments. *Education and Information Technologies, 3*(2), 137-148.

Murugesan, K., & M.Ibrahim, S. (2022). Understanding the role of pedagogies on adult's learning experience. *Journal of Research in Humanities and Social Science, 10* (7), 213-220. https://doi.org/10.13140/RG.2.2.32023.65447

Pantelidis, V. S. (2009). Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. *Themes in Science and Technology Education, 2*(1-2), 59-70.

Pérez, S. S., Lopez, J. M. G., Barba, M. A. V., Betancourt, R.O.J., Solís, J. E. M., Ornelas, J. L. R., García, G. I. R., & Haro, F. R. (2022). On the use of augmented reality to reinforce the learning of power electronics for beginners. *Electronics*, *11*(3), 302. https://doi.org/10.3390/electronics11030302

Pittman, V. V. (1987). The persistence of print: Correspondence study and the new media. *The American Journal of Distance Education, 1*(1), 31-36. https://doi.org/10.1080/08923648709526570

Ramalingam, S. (2023). ESL learners' qualitative perspective on learner-to-instructor interaction in blended environment. *Arab World English Journal, 9*, 234-248. https://doi.org/10.24093/awej/call9.16

Reeves, S. M., & Crippen, K. J. (2021). Virtual laboratories in undergraduate science and engineering courses: a systematic review, 2009-2019. *Journal Science Education and Technology, 30*(1), 16-30. https://doi.org/10.1007/s10956-020-09866-0

Shaukat, S. M. (2023). Exploring the potential of augmented reality (AR) and virtual reality (VR) in education. *International Journal of Advanced Research in Science, Communication and Technology, 3*(2), 51-56. https://doi.org/10.48175/IJARSCT-12108

Solmaz, S., & Gerven, T. V. (2020). Integration of interactive CFD simulations with AR and VR for educational Use in CRE. *Computer Aided Chemical Engineering, 48*, 2011-2016. https://doi.org/10.1016/B978-0-12-823377-1.50336-0

Tamez, C. V. (2014). Lifelong learning principles and higher education policies. *Tuning Journal for Higher Education, 2*(1), 91-105. https://doi.org/10.18543/tjhe-2(1)-2014pp91-105

Wang, C., Tang, Y., Kassem, M. A., Li, H., & Hua, B. (2021). Application of VR technology in civil engineering education. *Computer Applications in Engineering Education, 30*(2), 1-14. https://doi.org/10.1002/cae.22458

Xie, J., Yan, Z., & Wang, X. (2023). VR-based interactive teaching and practice environment for supporting the whole process of mining engineering education. *Mining Technology, 13*(2), 89-105. https://doi.org/10.1080/25726668.2023.2177737