Enhancing Student Engagement in Engineering and Education through Virtual Reality: A Survey-Based Analysis

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***Abstract*—This paper investigates the impact of virtual reality (VR) on student engagement in engineering education and their potential in enhancing the student learning experience through technology-led learning. VR technology has shown to improve student engagement in different educational sectors. As a result, this study evaluated the efficacy of VR technology as an immersive learning tool focusing on engineering education. The survey collects data from a diverse sample of students who experienced the use of VR-based flight simulator as a part of their continuous assessment, providing valuable insights. Conditional results indicate that by using VR headsets 70% of students reported improved learning outcomes for the module, while 100% students agreed that VR technology offered a more immersive learning experience. The survey results indicate and emphasize the potential benefits that integrating VR headsets into engineering education could bring to the student learning experience through enhanced student engagement and the acquisition of practical skills in simulated immersive environments. The paper also makes recommendations for further research and implementation of VR technology in other fields of STEM education.**

Keywords—Virtual reality, Student engagement, Engineering education, Immersive learning, Educational technology, Technology-led teaching

I. Introduction

Practical hands-on experience is one of the key cornerstones of engineering education. As a result, it is essential that practical hands-on experience forms a part of any engineering module being taught. The use of Project-Based Learning (PBL) can provide practical hands-on experience to the students. This promotes higher learning as it is a student-centred approach to education whereby learners actively collaborate and engage in investigating a real-world problem or challenge. Research indicates that PBL is extremely suitable for engineering education due to its similarities with the professional practice of engineers [1]. PBL has also had a very positive impact on students' motivation and has shown to improve retention of students and enhance the quality of engineering education [2]. Thus, it is essential that engineering education incorporates the PBL in the curriculum.

The use of flight simulators to demonstrate Aircraft Performance characteristics is one such example of PBL. Flight simulators have several benefits for students including the ability to record flight parameters, visualisation of real flight parameters thereby promoting visual based learning and providing a simulated flight experience for the students to correlate theory with practical experience [3]. However, many flight simulators used in engineering education might not provide a completely immersive experience mainly due to different levels of fidelity, haptics experience as well as only providing frontal immersion. Fig. 1 shows an example of a static flight simulator. The students may not get a spatial view of the cockpit environment and thereby not fully replicating the real-world experience of flying [4]. Full motion flight simulator as also shown in Fig. 1 replicate realistic conditions, but such simulators are used for pilot training and generally are too expensive for universities to provide a comparable experience for students. Due to the immersive nature of the Virtual Reality (VR) technology, a similar flight experience could potentially be achieved at a fraction of the cost compared to commercially available simulators.

Fig. 1 Left: static flight training device by CKAS (ckas.com.au). Right: full-motion flight simulator at Airbus (flightsafety.com).

VR-based technology-led learning has shown great potential in the recent years. Studies have shown that the use of VR leads to more interest and engagement from the student while they are immersed in a virtual environment thereby greatly enhancing the learning environment and increasing the attention span of the students to the subject matter being taught [5]–[7].

In this paper, VR headsets were used in conjunction with the flight simulator and a survey was conducted to gather information about the student experience of using the flight simulator with VR, including their perceptions of its effectiveness as a teaching and learning tool as well as the advantages and disadvantages of using a VR based flight simulator. The results of the survey were used to inform an ongoing reflective exercise to improve course and curriculum content. Reflective exercises form a critical part of course and curriculum development and has demonstrated significant improvement in teaching quality and student engagement in many studies [8].

II. Implementation of VR Flight Simulation Lab

The VR Flight Simulation Laboratory was implemented at the University of Glasgow for modules offered in Singapore in partnership with Singapore Institute of Technology. The lab was designed to provide a PBL environment for several modules in the undergraduate Aerospace Engineering programme. The programme has been introduced in 2019 in Singapore with an emphasis on new technologies and unmanned systems. To promote active learning, the programme incorporates PBL in almost all its modules. This is reflected by the maximum exam weightage for all modules capped at 35%. By implementing novel technologies for teaching in the curriculum, including VR, data analytics, drones and internet of things, we aim to equip students with new skills required to work as a professional engineer, and to excite them about future technologies in the aerospace industry.

However, it is important to evaluate the usefulness of such technologies in PBL to promote student learning and engagement. Hence, in this paper we use the example of the Aircraft Performance module for the evaluation of the VR technology. Aircraft Performance is a second-year module with 5 (ECUK) credits, and the assessment is divided into quiz (35%), exam (35%) and laboratory (30%). The overall aim of the module is to equip students with the understanding and knowledge to evaluate the performance of fixed-wing aircraft over a typical civilian mission profile (take-off, climb, cruise, approach, landing). Flight experiments therefore provide students with the opportunity to apply the theoretical aspects in flight tests. The Royal Aeronautical Society (RAeS) recognises the importance of such flight tests and has made it a requirement for the accreditation of aerospace engineering programmes (BEng and MEng) in the UK [9] . To facilitate this, Cranfield University has modified a Jetstream 31 aircraft as a flying classroom to conduct flight test campaigns for engineering degree accreditation [10]. However, RAeS recognises the capabilities of flight simulators to provide a realistic learning experience for students that complements practical flight tests. While many flight simulators implemented at universities provide students with the procedural experience, most simulators are fixed and lack the immersion to truly appreciate the handling qualities and flight dynamics. The developed VR Flight Simulation Laboratory therefore uses VR headsets to provide the extra level of immersion during flight experiments.

During the Aircraft Performance laboratory, students are required to fly complete missions using models of the Cirrus SR22 and Cirrus Vision SF50 aircraft for the analysis of propeller and jet aircraft performance, respectively. The missions include the following tasks:

- Mission 1: In cruise condition, determine the maximum velocity near sea-level.
- Mission 2: In cruise condition, determine the stall speed near sea-level.
- Mission 3: In cruise condition, determine the maximum endurance and range velocities.
- Mission 4: Fly sawtooth manoeuvres to estimate relevant aircraft parameters related to Missions 1-3.
- Mission 5: Based on the findings from Missions 1-4, fly an emergency descent glide to safely land at a nearby airport.

Students are grouped in pairs to complete these missions for both aircraft configurations using the flight simulator.

A. *Flight Simulation Environment (without VR headset)*

The original flight simulation environment has been implemented using X-Plane 11. X-Plane 11 is a realistic flight simulation software developed by Laminar Research [11].

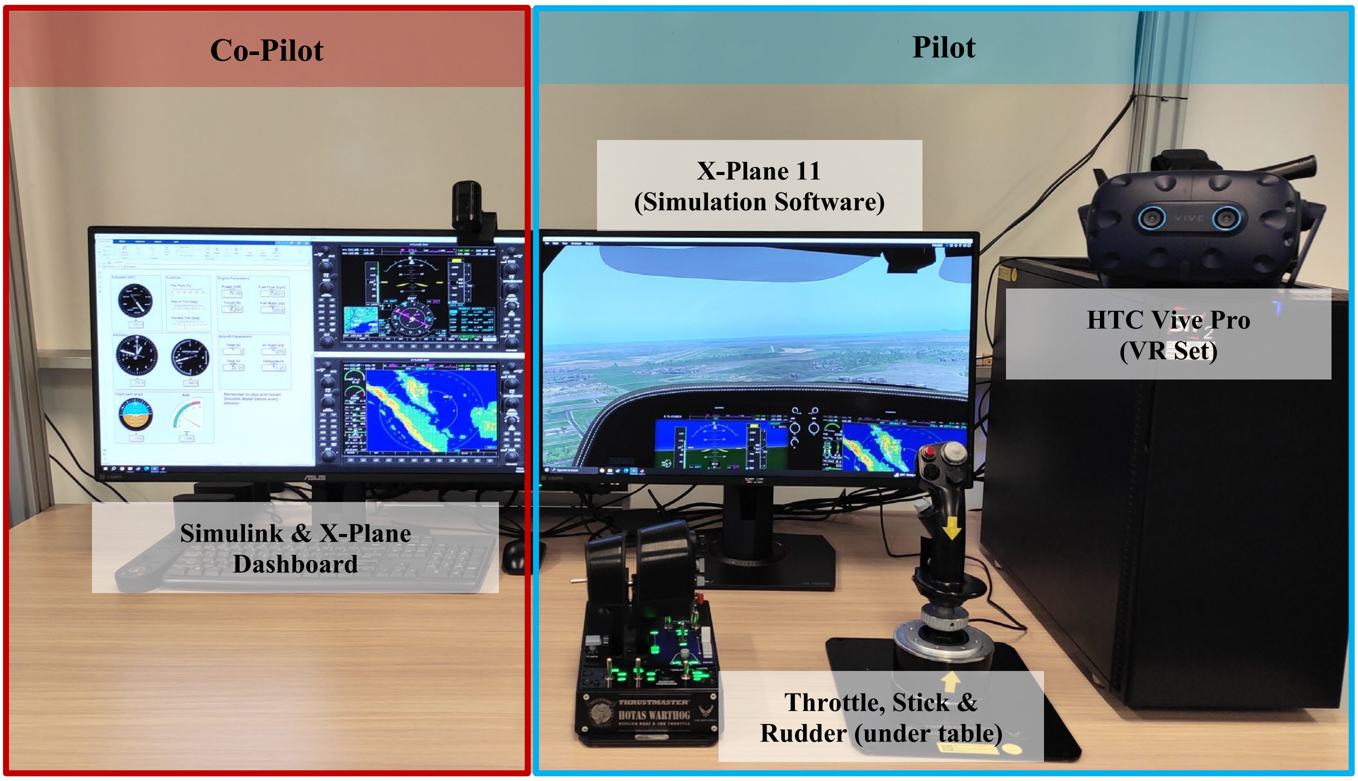

Fig. 2 VR-based flight simulation framework with pilot VR headset & controls (right) and co-pilot dashboard view (left)

Fig. 3 X-Plane 11 model of the Cirrus SR22 Turbo G6 [12]

It can be used as a tool to test and evaluate a variety of designs. Unlike most commercial flight simulation software, which use aerodynamic look-up tables, X-Plane captures the full flight physics of the aircraft, including aerodynamic models, six-degree-of-freedom equations of motions and propeller models for the propulsion system. X-Plane therefore provides an accurate and realistic simulation environment for this lab to allow students to analyse the performance through simulated flight experiments. Fig. 3 shows example of the Cirrus SR22 implemented in X-Plane 11.

As shown in Fig. 2, the lab experiment has been developed to mimic realistic cockpit environments with 2 students taking the roles of pilot and co-pilot, respectively. The lab uses high-end controllers (stick, throttle, and rudder pedals) to provide the pilot with a realistic haptic experience. Using the controllers, the pilot has full control of the aircraft to manoeuvre, adjust thrust, deploy flaps, trim the aircraft, and activate autopilots. In the original flight simulation environment without VR, the pilot sees a dedicated monitor showing the pilot view of surrounding and cockpit. The view is fixed, and the pilot cannot look around without using the mouse.

Fig. 2 further illustrates the space of the co-pilot which has a dedicated monitor with replicas of the instrument panel in the cockpit (same instruments as in pilot view). Mimicking typical operations during the flight, the co-pilot is instructed to assist the pilot by calling important flight parameters, such as altitude, climb speed, speed, or fuel burn. Fig. 4 shows an example of 2 students taking the roles of pilot and co-pilot. The additional dashboard (far left in Fig. 2) allows the co-pilot to monitor additional parameters that are not typically available to pilots in real aircraft. The additional screen has been implemented in Simulink to display and record all parameters during a flight mission for post-processing. The UDP interface protocol in X-Plane 11 is used to stream data to Simulink using virtual serial ports.

B. VR-Enabled Flight Simulation Environment

To develop a testbed for VR-based flight simulation, the project implemented the latest off-the-shelf VR technology shown in Fig. 2 (far right). The HTC Vive Pro is a room-scale VR headset which can provide a fully immersive first-person experience. The HTC Vive Pro connects wirelessly to the computer and can be readily integrated with the X-Plane simulation framework. Since the original lab was designed such that, the pilot does not remove the hands from the controllers, we were able to seamlessly extend the existing flight simulation lab with the VR headset. The headset can track its motion which allows the pilot to look around the cockpit and even look out the window to see the environment and aircraft state, e.g., if flaps have been fully deployed. This provides a much more dynamics and immersive experience compared to the static condition in the original simulator.

Fig.4 shows the evaluation phase of the VR implementation with undergraduate students during the Aircraft Performance session. The pilot is seen wearing the VR headset while the co-pilot provides instructions of important flight parameters. Although the HTC Vive Pro had the best resolution at the time of implementation, the low resolution of the VR technology hinders the pilot from seeing all flight parameters to correctly fly the required mission. It is therefore critical that the co-pilot provides assistance during the flight. As the pilot is not aware of the surrounding, the co-pilot can also help to guide the pilot around the physical space.

Fig. 4 Students taking roles of pilot and co-pilot during the flight experiment. Pilots are using the VR headset here.

III. Survey Methodology and Data Collection

The methodology for this paper involved a comprehensive approach that involved collecting data using a questionnaire-based survey that was designed using existing surveys and tailoring the survey to ensure that student engagement can be gauged from this survey [8], [13], [14]. The questionnaire was distributed to all students during the flight simulator lab session for the Aircraft Performance module and the students were asked to provide their feedback of using the flight simulator with and without the VR headsets. Students were provided with a QR code to participate in the questionnaire. The survey was designed to be completely voluntary and anonymous. By employing this approach, the study aimed to gather a comprehensive perspective on students' experiences, difficulties, and their perception of the impact of these VR headsets on their learning experience.

Data collected from the survey is presented below. A total of 16 students completed the survey. Fig. 5 represents the percentage of students that had used a VR based immersive learning laboratory for their studies as well as the frequency of their usage.

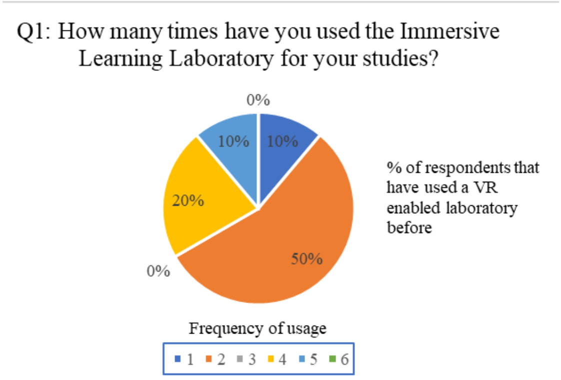

Fig. 5 Frequency of usage for immersive learning laboratories

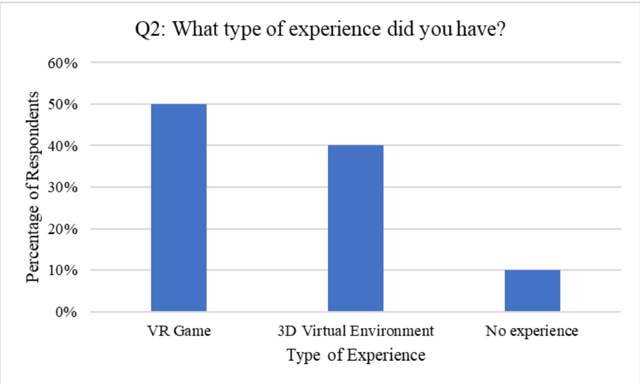

Fig. 6 Type of virtual environments experienced by the respondents

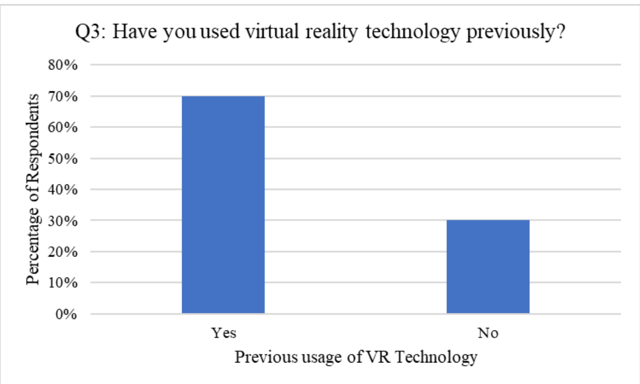

Fig. 7 Previous usage of VR technology by respondents

The respondents were also asked about their impressions on using the VR headsets for the flight simulator. The word cloud shown in Fig. 8 represents the responses from the students. The size of each word represents the frequency of occurrence for each word from the survey results.

Fig. 8 First impressions of using VR headset technology

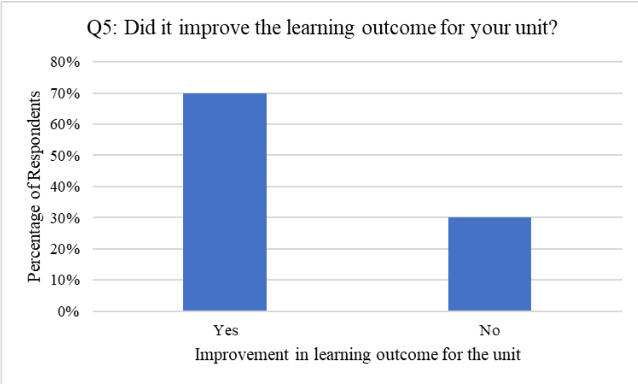

Fig. 9 Improvement in learning outcome for the unit

The respondents were asked to highlight their likes after using the VR headsets. The key comments from the students are highlighted in the form of a word cloud as shown in Fig. 10. Similarly, the respondents were also asked about their dislikes after using the VR headsets as shown in Fig. 11.

Fig. 10 Respondents likes about the usage of the VR headsets

Fig. 11 Respondents dislikes about usage of the VR headsets

The respondents were then asked whether they felt any discomfort while using the VR headsets for the flight simulators.

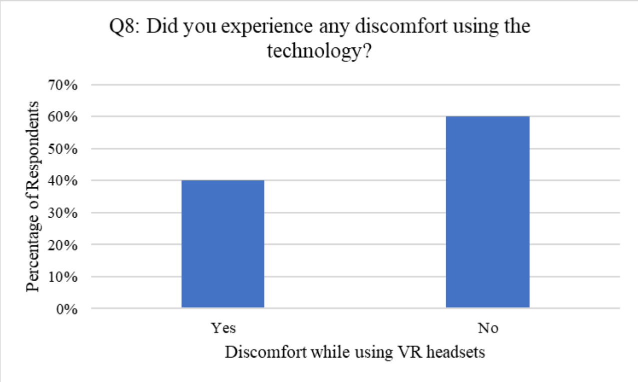

Fig. 12 Discomfort while using VR headsets

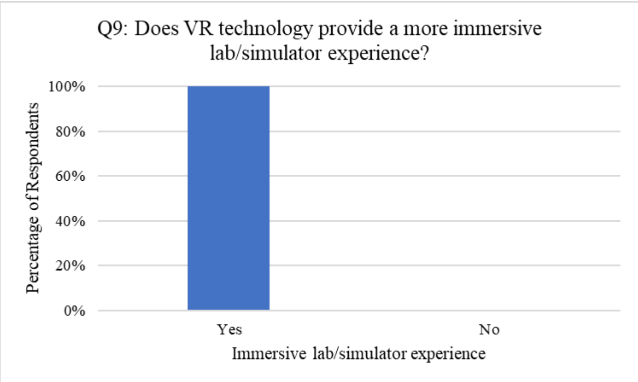

Fig. 13 Lab/simulator immersive experience of the respondents

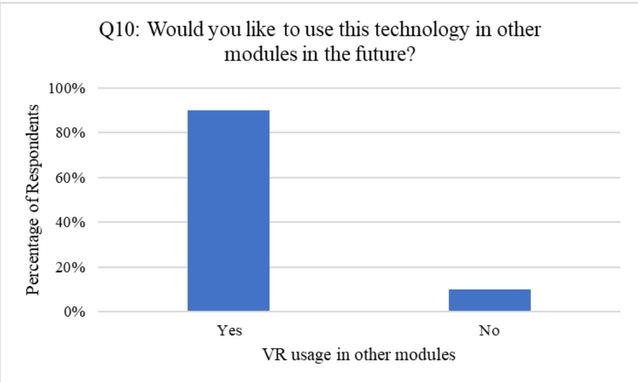

Fig. 14 Incorporation of VR technology in other modules

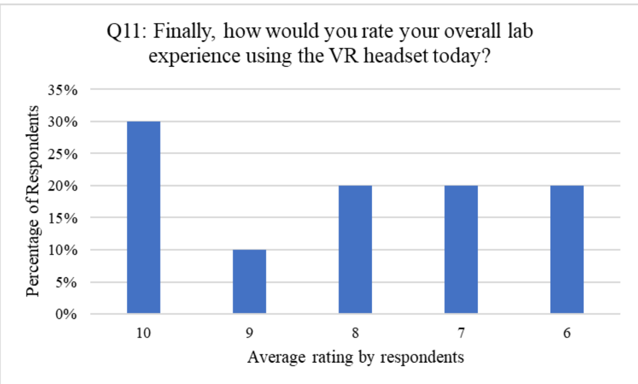

Fig. 15 Average rating of VR experience by respondents

The respondents were also asked to give some suggestions on the incorporation of VR headsets in other modules. This did not receive many responses apart from a couple of students indicating that they would like to use a similar technology in other labs such as wind tunnel experiments.

IV. DISCUSSIONS

Through the results of this survey, it was found that 65% of the respondents had prior experience with VR technology, either through gaming or through other 3D virtual experiences (Fig. 5 and Fig. 6) thereby indicating a growing acceptance and adoption of the technology among students. 40% of the participants expressed some form of excitement and positive experiences after using the VR headset which indicates the immersive and realistic experience provided by VR (Fig. 8 and Fig. 10). This relates closely to existing literature which indicates that the use of VR in a learning environment can significantly increase student motivation and engagement [15]. However, 15% of participants also experienced dizziness and/or motion sickness while using the VR headsets with other participants facing general discomfort (Fig. 11 and Fig. 12), highlighting a common challenge faced by many students in VR environments [16].

The study also revealed that approximately 75% of participants felt that the VR had a positive impact on their learning. The participants appreciated the interactive and engaging nature of the virtual flight simulator environment Fig. 9 and Fig. 13 . Participants particularly liked the realism and immersion of the technology, with 70% expressing their preference for these qualities (Fig. 10). However, concerns were raised by 40% of participants regarding blurry graphics, resolution issues, and occasional technical glitches, emphasizing the need for technical improvements (Fig. 11).

One of the most positive aspects from the survey was that 100% of the participants agreed that VR technology provided a more immersive flight simulator and lab experience compared to traditional methods (Fig. 13), thereby demonstrating its potential for creating engaging learning environments. This correlates very closely to existing research that indicated that undergraduate students had positive learning outcomes and experiences after engaging with VR teaching [17]. 85% of participants also indicated that there would be significant interest in using VR technology in other modules, underscoring a positive attitude towards future integration. Some participants also shared innovative ideas (15%) for utilizing VR in teaching, such as simulating wind tunnel observations or creating interactive hands-on activities. The overall lab experience using the VR headset received mixed ratings, with 60% finding it overwhelmingly positive with a 10, 9 and 8, and the remaining 40% providing lower ratings of 7 &and 6 (Fig. 15). This suggests that though the incorporation of VR headsets has been positive there needs to be improvement in certain aspects such as the comfort levels and the graphic resolutions to enhance and maximise the overall lab experience and improve student satisfaction.

V. CONCLUSION

This paper conducts a preliminary analysis on the experiences and perceptions of students regarding the use of

VR technology in a STEM subject based learning environment. The findings indicated a growing acceptance and adoption of VR among students, with 65% of respondents having used VR technology before. This lays credence to the notion that VR technology is becoming increasing prevalent and familiar for most students. The study also indicated that the students were excited about the use of VR for the flight simulator and had a positive experience of using the headsets for their flight simulator lab work. This highlights the immersive and realistic nature of the technology and aligns with existing literature that emphasises the positive impact of VR on student motivation and engagement. However, it is important to note that 15% of the participants experienced dizziness, motion sickness, or general discomfort while using the VR headsets, indicating that more needs to be done to alleviate some of the discomforts faced by the students. Despite this potential drawback, participants reported a positive impact on their learning outcomes and appreciated the interactive, immersive, and engaging nature of the virtual flight simulator environment despite there being concerns about the graphics and resolution provided by these headsets as well as technical glitches that beset the VR usage.

One of the key findings from the study was that all participants agreed that VR technology provided a more immersive lab experience and 85% participants wanted incorporation of VR in other modules. This high interest from the participants highlights the potential of using VR in STEM based subjects. However, the overall lab experience using the VR headsets received mixed ratings, suggesting that there is room for improvement in aspects such as comfort levels and graphic resolutions to maximize the overall lab experience and student satisfaction. These findings emphasize the need for continuous advancement and optimisation in VR technology to ensure a positive impact on the learning experience of the students.

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