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Plant Anatomy Practicum Assisted by Online Microscope Viewer to Enhance Students' Kinesthetic Bodily Intelligence

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Abstract: Initial conditions of plant anatomy practical learning at Wiralodra University indicate a lack of training in students' kinesthetic bodily intelligence. This is evident as students do not feel proficient in operating microscopes and determining microscope magnification, indicating a lack of trained kinesthetic bodily intelligence. Based on this issue, a digital microscope is needed to train students' kinesthetic bodily intelligence in plant anatomy practicals. The innovation of digital microscope technology is necessary as a supporting tool for plant anatomy practicals. The objective of this study is to develop an Online Microscope Viewer to enhance students' multiple intelligences in plant anatomy practicals. Considering the nature of the study as the development of an Online Microscope Viewer, the research design used is Research and Development. The study subjects consist of 185 second-semester biology education students from the Biology Education program at Wiralodra University, divided into five classes. The sampling method used is cluster random sampling, with two classes, Bio B (experimental group) and Bio D (control group), selected under the condition that the populations are homogeneous. The results indicate that the developed Online Microscope Viewer used in plant anatomy practicals is highly valid. The developed Online Microscope Viewer can significantly enhance students' kinesthetic bodily intelligence in plant anatomy practicals, categorized as high. There is a significant difference in the improvement of students' kinesthetic bodily intelligence between the class using the Online Microscope Viewer and the class using binocular light microscopes.

Keywords: Plant anatomy practicum; Online microscope viewer; kinesthetic bodily intelligence; University student

Introduction

During the COVID-19 pandemic, all activities were restricted, and everything, including schooling, had to be done from home. This posed challenges for educators and students in conducting teaching and learning activities, especially in the field of plant anatomy, which requires practical observation of cells using microscopes and cannot be done face-to-face. In plant anatomy learning, it is not only the concepts that need to be mastered but also the practical skills.

Based on a survey conducted among biology education students at a university in Cirebon, Indonesia, it was found that 97.14% of students felt they were not facilitated in operating microscopes during plant anatomy practicals, 91.43% of students felt they were not facilitated in determining magnification on microscopes during plant anatomy practicals, 74.29% of students felt their ability to count observed cells during plant

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anatomy practicals was not facilitated, 80% of students felt their ability to analyze observed cells during plant anatomy practicals was not facilitated, 82% of students felt their ability to measure various observed cell shapes during plant anatomy practicals was not facilitated, 88% of students felt they were not facilitated in visualizing observation results during plant anatomy practicals, 91% of students felt they were not facilitated in identifying observation results during plant anatomy practicals, and 85% of students felt they were not facilitated in exploring their abilities to recognize various cell organelles and tissues in plants. Based on the survey results, it can be concluded that the initial conditions of plant anatomy practical learning at the university in Cirebon indicate a lack of facilitation in the plant anatomy learning process.

According to the survey on microscope needs, it was found that students greatly need a microscope that can facilitate cell observation, make it easier to visualize observation images clearly, facilitate the identification of observation results, and make it easier to measure and count observed objects. The Online Microscope Viewer (OMV) is one solution that meets these needs. The OMV is a digital microscope with a blended learning system that can be used both face-to-face and online. Digital microscopes are easy to use, and the quality of digital images is better than that of traditional microscopes (Hamilton et al., 2015). Digital microscopes can enhance learning productivity, efficiency, critical thinking, ease of communication, and student confidence (Tian et al., 2014). Digital microscopes can also be implemented interactively, combining elements of learning and gaming to explore students' observation abilities (Kim et al., 2016). The practicality of using digital microscopes can enhance students' understanding in histology practicals (Martínez et al., 2016). Digital microscopes can increase the learning activity of veterinary medicine students (Brown et al., 2016). The development and integration of digital microscopes into face-to-face approaches to teaching microscopic anatomy can result in changes in students' learning behavior, group work, and social interactions (Schmidt et al., 2014). Digital microscopes influence students' visual-spatial intelligence and numerical abilities (Achdiyat & Utomo, 2018).

Blended learning has several advantages, including facilitating active learning and providing insights to strengthen the quality of anatomy teaching and learning (Ngan et al., 2018), and effectively delivering histology learning content through blended learning laboratories in microscopic natomy, thereby increasing students' interest in learning (Barbeau et al., 2014), and 3) influencing students' learning motivation, critical thinking, and metacognition (Kassab et al., 2015), as well as the effectiveness of the learning process (Noour & Hubbard, 2015), student learning activities (Kavadella et al., 2014), clinical skills effectiveness (Mccutcheon et al., 2015), and student learning achievement (Al-Qahtani et al., 2013).

In line with the study by (Herodotou et al., 2020), students express satisfaction with blended learning-based instructional processes. The majority (80%) of students in the experimental group prefer blended learning over traditional face-to-face lectures (Smith & Suzuki, 2015). There is a significant difference in students' cognitive abilities and attendance between classes using blended learning and those that do not (Akyol et al., 2009). Students in the blended learning group perform much better than their counterparts in the conventional group in knowledge tests after the learning process (Kavadella et al., 2014).

Based on these issues, there is a need for the development of a digital microscope that can be used both face-to-face and online to facilitate plant anatomy teaching and learning. The development of the Online Microscope Viewer (OMV) is the right solution to address these issues.

Method

Design

The objective of this research is to develop the Online Microscope Viewer (OMV) to facilitate the process of plant anatomy learning. Therefore, the research design used in this study is Research and Development (R&D). The research and development method in the field of education was proposed by (Borg & Gall, 2003). It is described as "a process used to develop and validate educational products," which refers to the process used to develop and validate educational products.

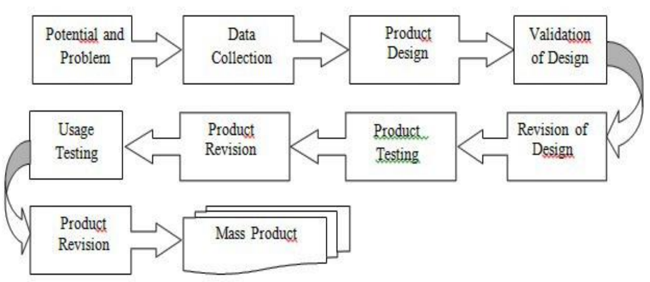

Figure 1. Flow of Research and Development (Borg & Gall, 2003)

The research procedures and steps followed the procedures and steps proposed by (Borg & Gall, 2003), who outlined ten steps for conducting research strategies. The main steps of Research and Development (R&D) can be described as follows, according to Borg and Gall (2003): The first step is Research and Information Collecting. Researchers gather relevant data and information related to their research topic. They conduct literature reviews, collect primary and secondary data, and study previous research conducted in the same field. The second step is Planning. Once the information is collected, researchers create a detailed plan to proceed with the research. They identify research goals, develop a theoretical framework, determine the research methods to be used, and plan the steps to be taken during the research process. The third step is Developing the preliminary form of the product. At this stage, researchers design and develop the initial form of the product or concept to be tested. They use the gathered information and previous research findings to aid in this development process. The fourth step is Preliminary field testing. After the initial product is developed, researchers conduct preliminary field tests to gather feedback and evaluations. The aim is to understand the strengths and weaknesses of the initial product and identify areas that need improvement. The fifth step is Main product revision. Based on the results of the preliminary field testing, researchers carry out revisions and improvements on the main product. They integrate the obtained feedback and make necessary changes to enhance the quality of the product. The sixth step is Main field testing. Once the revisions on the main product are completed, researchers conduct broader field testing. They test the product on a larger group or in a more realistic environment to gain a better understanding of its performance. The seventh step is Operational product revision. Building upon the results of the main field testing, researchers perform additional revisions and improvements on the product. They pay attention to user input and feedback and make necessary adjustments to ensure the product functions well in operational settings. The eighth step is Operational field testing. After the revisions on the operational product are done, researchers conduct comprehensive and extensive field testing in operational conditions. They test the product in real-life situations to ensure it meets the established requirements and expectations. The ninth step is Final product revision. Based on the results of the operational field testing, researchers carry out the final revisions on the product. They make the last changes and adjustments to ensure the product achieves the desired final quality. The tenth step is Dissemination and implementation. After the final product is revised, researchers disseminate their research findings to the intended audience. They may publish their findings in scientific journals, present them at conferences, or share them through other means. Additionally, they ensure that their findings are implemented and applied in relevant contexts.

These are the main steps in Research and Development (R&D) as outlined by Borg and Gall (2003). This process encompasses crucial stages that assist researchers in developing new products or concepts and ensuring their quality before widespread dissemination and implementation. The research design used to test the effectiveness of the product is a quasi-experimental design with a pretest-posttest control group design.

Sample

The subjects of this study are biology education students, consisting of 5 classes with a total of 185 students. The sampling method used is cluster random sampling to determine the readability of the developed Online Microscope Viewer in plant anatomy practicals with kinesthetic bodily intelligence competence. A large-scale trial is conducted using two classes, namely Bio B (the experimental group) and Bio D (the control group), with the condition that the populations are homogeneous.

Instrument

The data collection instrument in this study is the MVO usage test instrument. The test instrument consists of 5 essay questions that are administered during the plant anatomy practical exam using the MVO.

Data Collection and Analysis

The data analysis techniques consist of test trial analysis and large-scale data analysis. The results of the item validity show that all items can be considered valid, with the calculated r-value > the table r-value of 0.3673, and all items in each variable used in this study have reliability with a Cronbach's Alpha coefficient of 0.933. The analysis of the facilitation of plant anatomy learning is conducted after the main field testing (large-scale trial). In order to answer the research questions, the data are analyzed using the N-Gain score test, prerequisite test, and independent sample t-test.

Result and Discussion

Development Product

Based on the problem identification, a draft design in the form of a web application storyboard for the MVO and the modification of a light microscope into a digital microscope that can facilitate plant anatomy learning was created. The main focus of this research is to develop the MVO application. As for the digital microscope used, it is a modified light microscope that can be transformed into a digital microscope using a smartphone, a 100x magnification telescope, and the DroidCam application. The process involves the following steps: replacing the eyepiece lens of the light microscope with a telescope equipped with a clamp, clamping the telescope onto the smartphone's rear camera, installing the DroidCam application on both the smartphone and PC (laptop/notebook), and configuring DroidCam as the camera and establishing a connection between the PC (laptop/notebook) and the smartphone on the light microscope. This can be seen in Figure 2.

Figure 2. Modification of Light Microscope into Digital Microscope

The design of the MVO web application begins with the adjustment of the web interface's color scheme, login and register features, profile, home, dashboard, friend list, inbox, activities, and various other tools. The blended learning-based digital microscope web can be accessed at https://microscopblended.com. This can be seen in Figure 3.

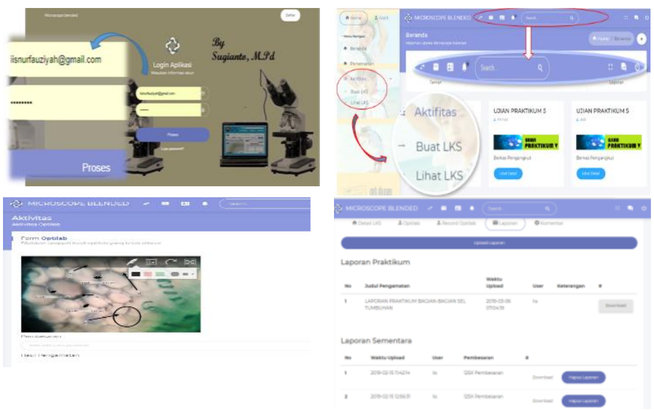

Figure 3. Mikroskop Viewer Online Application.

The development of Mikroskop Viewer Online has introduced a new wave of digital microscopes, particularly targeting the field of education. These latest types of digital microscopes mentioned by Emily (2020) offer a diverse range of features and applications. First, the Kooletron Digital Microscope stands out as a portable handheld device suitable for exploring various science subjects. Its versatility makes it a valuable tool for educators and students alike. Second, the Plugable Digital Microscope is designed with elementary school students in mind. Its capabilities include identifying garden parasites and analyzing objects like jewelry, stamps, and coins, making it an ideal choice for young learners. Next, the Celestron Digital Microscope caters to both high school biology classes and elementary students. This microscope impresses with its ability to capture high-resolution images and videos using high-quality glass lenses, ensuring sharper visual output. The Yinama Digital Microscope boasts a sturdy and weighted base, making it resistant to vibrations, which helps maintain image focus during observation. For those seeking mobility and convenience, the Tsaagan Digital Microscope comes into play. With its compatibility to be connected to mobile phones, users can easily carry and use it on the go. Additional models like the Celestron Digital Microscope Type 44341, Amscope Digital Microscope, Celestron Penta Digital Microscope, and Omax Digital Microscope expand the array of options available for educators and researchers. Each of these microscopes offers distinct features catering to specific educational and scientific needs. In conclusion, the introduction of Mikroskop Viewer Online and the variety of digital microscope models mentioned by Emily (2020), revolutionize the educational landscape, empowering students and educators to explore the microscopic world with enhanced clarity and convenience.

Analysis of Test Data

To determine the average test scores for the facilitation of plant anatomy learning in the experimental and control groups, an N-gain score test needs to be conducted. Table 1 shows the N-gain score test results for kinesthetic intelligence.

Table 1. N-Gain Score for the Facilitation of Plant Anatomy Learning using MVO

	Group		Statistic	Std. Error
N-gain	experiment	Mean	0.8431	0.01022
		Minimum	0.67	
		Maximum	0.95	
	control	Mean	0.3946	0.01851
		Minimum	0.06	
		Maximum	0.53	

Based on the calculation of N-gain scores for the facilitation of plant anatomy learning using MVO in Table 1, it shows that the average N-gain score for the experimental group (using MVO microscope) is 0.8431, categorized as high. The N-gain score ranges from a minimum of 0.3 to a maximum of 0.7. Meanwhile, the average N-gain score for kinesthetic intelligence in the control group (using light microscope) is 0.3946, categorized as moderate. The N-gain score ranges from a minimum of 0.3 to a maximum of 0.7. It can be concluded that the experimental group using the MVO microscope has a high category in facilitating plant anatomy learning. On the other hand, the control group using the light microscope has a moderate category in facilitating plant anatomy learning. Bouker & Scarlatos (2013) showed that digital microscopes can train physical skills, thus improving kinesthetic intelligence and enhancing memory performance. Furthermore, the study by Sasidharakurup et al. (2015) demonstrated that the use of blended learning-based virtual biotechnology laboratories can enhance academic kinesthetic intelligence. Online learning for teaching clinical skills is equally effective as traditional methods, and the blended learning approach in teaching clinical skills in nursing education is effective (Mccutcheon et al., 2015).

Hypothesis Testing Results

The next step is to test the hypothesis to determine the difference in the facilitation of plant anatomy learning between the group using the MVO microscope and the group using the light microscope. Therefore, an independent sample t-test needs to be conducted. The assumptions for using an independent sample t-test, according to Singgih (Santoso, 2017), are that the two samples are not paired, the data used in the test are quantitative data (raw numbers) on an interval or ratio scale, the data for both samples are normally distributed, and there is equality of variances or homogeneity for the two sample data (although not an absolute requirement). The normality assumption test for the experimental group and control group can be seen in Table 2.

Table 2. Normality Test for Kinesthetic Intelligence N-Gain Score Data in the Experimental and Control Groups

	Grup	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Gain Skor	experiment	0.135	37	0.087*	0.909	37	0.051
	control	0.082	39	0.200*	0.990	39	0.975

The significance value (p) in the Kolmogorov-Smirnov test is 0.08 for the experimental group and 0.2 for the control group ($p > 0.05$), indicating that based on the Kolmogorov-Smirnov normality test, the data is normally distributed. Therefore, it can be concluded that the N-gain score data for the experimental group and the control group are normally distributed, allowing for the subsequent independent sample t-test. The independent sample t-test results can be seen in Table 3.

Table 3. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
			Sig.	t	df	Sig. (2-tailed)
Gain	Equal variances assumed	2.076	0.154	23.623	74	0.000
	Equal variances not assumed			23.729	73.018	0.000

Based on Table 3, the value of Sig. Levene's Test for Equality of Variances is 0.154 > 0.05, which means that the variance of the Gain data between the experimental and control groups is homogenous or equal. Therefore, the interpretation of Table 3 is based on the values in the "Equal variances assumed" section.

Based on the "Equal variances assumed" section in Table 3, the Sig. (2-tailed) value is 0.00 < 0.05, and the t-value is 23.623 > the t-table value of 2.376. According to the decision-making basis in the independent sample t-test, this indicates a significant difference between students using MVO microscope (experimental group) and students using a light microscope (control group) in facilitating plant anatomy learning. Therefore, it can be concluded that H1 is accepted, and H0 is rejected.

This research finding can be supported by the study conducted by Tian et al. (2014), which showed that the test scores in the digital microscope group showed a significant improvement compared to those in the light microscope group ($p < 0.05$). The implementation of digital microscopes has enhanced teaching and learning in practical classes in histology laboratories and facilitated consolidation and revision of materials outside the laboratory (Gatumu et al., 2014). Virtual microscopes can improve collaborative group work and can be used more efficiently (Triola & Holloway, 2014). The Virtual Microscope Database (VMD) facilitates the use of virtual microscopes for research and teaching. VMD also has great potential to enhance the quality of histology and pathology learning and make this subject more accessible to students in educational institutions worldwide (Lee et al., 2018). Similar to how digital microscopes can train physical skills and improve kinesthetic intelligence, the Brain Rank application can also enhance kinesthetic intelligence by providing physical training and improving memory performance (Bouker & Scarlatos, 2013). Smart learning environments and blended learning models can improve students' knowledge of programming (Kose, 2012). Replacing optical microscopes with digital microscopes in histology practical's not only saves costs but also improves students' understanding (Martínez et al., 2016). There is an overall improvement in student performance in both veterinary schools using virtual microscopes and glass slide microscopes, but in terms of student assessment of the use of digital slides and microscopes, digital technology has been identified to have many advantages (Brown et al., 2016).

The development and integration of new virtual microscopes into face-to-face approaches for teaching microscopic anatomy can result in changes in student learning behavior, such as group work and social interaction (Schmidt et al., 2014). The research results indicate a significant influence on visual-spatial intelligence and numerical ability on mathematics learning achievement. The research results show significant differences in social and cognitive presence between the two course formats and higher perceptions of presence in blended learning processes (Akyol et al., 2009). The research results show statistically significant differences among the three methods in terms of students' learning achievement and preference for blended learning (Al-Qahtani et al., 2013).

The results of partial least squares structural equation modeling (PLS-SEM) analysis revealed that student engagement in face-to-face mode has a significant positive effect on their engagement in management-based and web-based learning modes. Additionally, the use of time and learning management tools based on system management has a positive influence on student learning performance in a blended learning environment (Baragash & Al-Samarraie, 2018). E-Learning directly influences peer learning and students' critical thinking but indirectly affects metacognitive regulation. Resource management, time management, and learning environment regulation strategies directly affect students' exam scores (17% of the variance explained) (Kassab et al., 2015).

Students in the blended learning group outperformed their counterparts in the conventional group in post-course knowledge tests, and female students in the blended learning group performed better than male students (Kavadella et al., 2014). The research results show that competence does not affect the IM (Interest/Enjoyment) and AM (Academic Emotions) dimensions. This means that competence does not influence students' motivation to accept the Blended Learning concept but indicates that competence influences EM (Effort/Importance) (Noour & Hubbard, 2015).

Conclusion

The results of the development of the Online Microscope Viewer (MVO) show a high category in facilitating plant anatomy learning, and there is a significant difference in plant anatomy learning facilitated between the class using MVO and the class using a light microscope.

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Author Contributions

The main author, contributed to designing research, conducting research, and writing research articles. The second author, played a role in guiding the research to writing articles. The third author, played a role in assisting in the implementation of the research and preparing the research instruments used in data collection. The fourth and five author, assisted in the data collection process. All authors have read and agree to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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