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Designing a Simple Microscope as an Alternative Learning Media with SolidWorks Software

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ABSTRACT

Microscopes are essential as media or teaching aids for prospective educators to achieve learning goals. However, there are still obstacles in their application in the form of quite expensive costs. Often, educational aids have a sizeable nominal value for a school. Teaching aids are costly and prone to damage or loss if students use them frequently, and it is difficult and expensive to find replacements if they are damaged, so teachers are afraid to use them. To overcome this problem, this study provides another alternative design, namely the design of teaching aids that are still useful and function well for learning through the design of microscope teaching aids. The research method used is a model research design using Solidworks software. The development of learning tools compiled in this study refers to the type of 4-D development (Four-D model), which consists of 4 stages: the define stage, the design stage, the development stage, and the dissemination. The research carried out three stages, namely the definition stage (Define), the design stage (Design), and the development stage (Develop). In the results of the design draft, questions were asked of the informants; it was concluded that a proper microscope was a microscope that worked according to its specifications, namely being able to see tiny or micro-objects. The clarity of the lens and the maximum magnification are also factors in the feasibility of the microscope. This research can be concluded as a simple microscope design using the Solidworks application, which is suitable for use as an alternative learning media. If the design of this tool is to be made, then the selection of materials and mechanisms needs further research and trials.

Introduction

Learning tools and media are essential components in the learning process that cannot be ignored. Prospective teachers can learn about the appropriate use of media to achieve learning objectives. The learning media component is essential for prospective teachers to effectively deliver learning information and the teaching and learning process (Smith et al., 2015). The learning media functions as a learning resource for students to receive messages and information from the teacher so that learning materials can be further refined and knowledge formed for students (de Menéndez & Morales-Menendez, 2019). Learning media can clarify the presentation of messages and information to facilitate and improve the learning process and value.

The development of technology in all fields, including education, and the world of education today need to be associated with the application of technology. Innovation and creativity in its application in education are also increasingly advanced (Okolie et al., 2021). Teachers or lecturers are competing to connect learning with the use of technology. However, the implementation still has an obstacle: the high cost. Usually, educational accessories are of high value to schools. Teaching materials are expensive, easily damaged, or lost if used frequently by students; if damaged, it is difficult to find a replacement and costly,

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so teachers are reluctant to use them (OIKAWA & Murakami, 2005). With limited costs, another alternative is to design educational materials that are still useful and function well for learning. One of them is the design of microscope accessories.

Props are tools that can demonstrate or explain theoretical concepts. The props themselves can be actual objects, pictures, and diagrams. Teaching aids are learning tools with various objects representing the lesson's content (Novak, 2022). The design of the microscope as a learning aid is included in the supporting section by design type (Saputra et al., 2021). Media by design are learning materials designed, prepared, and produced by the teacher, then used for the learning process. One of the learning materials is a microscope teaching tool (Zhang, 2022).

Many objects in the neighborhood are thrown away. Utilizing the things around you can undoubtedly bring various benefits. In addition, reducing waste from using used items in product manufacturing can reduce costs. Regarding second-hand items microscope accessories can also be made from second-hand items (Saputra et al., 2021). Using old objects as simple optical teaching aids can increase students' learning motivation. In addition, this study's design of the optics teaching device was straightforward.

Technological developments also affect the process of using educational materials. One of the applications of technology as an educational tool is gadgets. The use of gadgets is because gadgets are technology that everyone owns (Anwar, Kholifah, Nurtanto, 2022). This study's results show that using a utility camera or mobile phone as a magnifying lens is consistent with the formation of shadows on a similar microscope that uses two convex lenses to produce the features of natural shadows, inversion, and magnification (Melati et al., 2023). The results of smartphone-based digital microscopes are more precise and detailed than analog microscopes.

Technological developments make it possible to design educational materials that can be produced using SolidWorks software. Solidworks is an automation-based software that creates 3D solid models for research using Windows graphics (Budi & Sukmono, 2023). The use of software is relatively easy because it depends on the engineer's desire to learn the software. Development of learning materials based on Solidworks animation video software that can be used as learning aids and learning facilities, both physical and media (Seungoh Paek & Black, 2023). Previous research has used an animated learning video system. At the same time, the author's research uses a 3D design modeling system.

In this study, the authors would like to ask questions about the feasibility of designing a teaching tool under a microscope and the impact of designing a teaching tool under a microscope on future physics teachers. The purpose of this research is to fulfill the standards related to the suitability of microscope teaching tools and the factors that influence microscope teaching tools for prospective physics teachers. The results of the study are expected to help design microscope teaching tools that meet the appropriate standards and determine the success of microscope teaching tools for prospective teachers.

Methods

In this study, the authors used a qualitative method. This research method was chosen because the author's research data represents a practitioner's point of view and is limited to the design of tools. The research method used is the learning device development research design model made in this study and is a type of 4-D development (Four D model) that consists of 4 stages, namely defining, designing, developing, and disseminating (Aldoobie, 2015). The research carried out three stages: define, design, development, and communicate.

4-D (Four D Model) models 3D microscope design with SolidWorks software. The Define stage is a stage that aims to determine and define learning needs by analyzing the objectives and limitations of the material. This phase aims to identify and define learning needs by examining the goals and constraints of learning materials. This phase has three stages. Namely:

a) Initial Analysis
   At this stage, the needs of teaching materials are analyzed at the micro level to identify fundamental problems related to teaching materials to be developed. Develop learning materials and analyze appropriate external learning theories.
b) Analysis of Props
   At this stage, the microscope's components and suitability criteria according to the relevant theory were analyzed. Identifying the parts and conditions of the microscope that are suitable for its intended use allows SolidWorks graphics processing software to design a microscope stand based on its measurements. The identification of parts and their validity using the microscope are checked against theoretical criteria.
c) Analysis of replacement parts

At this stage, an analysis is carried out of the elements that the elements around them can replace.

This stage helps design the learning tools you will develop, especially learning materials based on SolidWorks graphics processing software. This step includes two stages, namely:

a) Initial design
   In this step, a design sketch of the essential elements of the microscope is made.
b) Final design
   Design sketches are made at this stage, especially in replacement parts.
c) 3D model design
   The specific design is done using SolidWorks software in this step.

The author surveyed the feasibility of designing tools for the Physics Department at UNY. The interview aimed to determine the feasibility of designing the educational materials created. The questions included answers about the importance of using microscope materials, the ideal use of microscopes for students, and the resulting instrument design. This research design can be explained as follows.

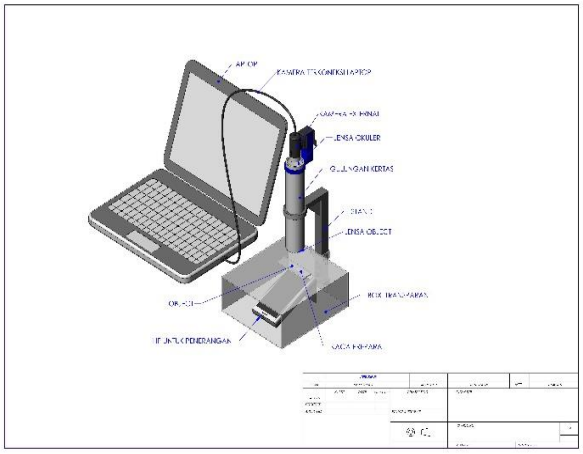
a) Research the materials used in the microscope to find out the commonly used tools and the suitability of the equipment.
b) Designing microscope textbooks using graphics processing software.
c) Hacking the suitability of microscope teaching materials.
d) Prospective teachers evaluate the design of microscope materials.
e) Evaluate the completeness of microscope teaching materials.

The results of the interviews are interpreted in the "Results" and "Discussion" sections of this article.

Result and Discussions

Microscope design using Solidworks software (Figure 1) was chosen because of its diverse usage tools and ease of learning. Modeling tools are used to design the layout. Software that is open source is a factor of consideration. This microscope design replaces some common parts of the microscope with commonly found objects. The microscope tube is replaced with a roll of manila paper. The microscope arm is replaced with an iron stand clamp. The reflector and diaphragm can be replaced with a cell phone as an illumination source and intensity control. Magnification is possible using an external camera connected to a laptop device. The external camera used has a minimum specification of 50 MP. The preparation of glass and objective ocular lenses is still required.

Figure 1
Microscope Design



Given the complexity of the emerging themes, each sub-theme presented a discussion that built on the theme.

1. What the interviewee knows about microscopes

A total of 14 interviewees gave opinions on what the microscope knows. All of the interviewees' views point to the function of the microscope as a tool that can see small objects. The majority of interviewees gave answers related to undersized or micro-objects. There is one opinion about the microscope as a tool to see bacteria. Bacteria can be categorized as micro-sized and small creatures. Interviewee H explained what he knew about microscopes.

"I know that a microscope is an optical instrument used to observe tiny (micro) objects. (Interviewee H)"

The interviewee's opinion is based on the definition of a microscope used to observe tiny objects. A microscope is a tool to see small objects clearly and correctly. (Subali et al., 2020)

2. Importance of Microscope

A total of 14 interviewees gave opinions on the importance of microscopes. There were two significant opinions on the significance of microscopes, namely, essential and not too important. Interviewees who stated the importance of a microscope argued that using a microscope is necessary to see crowns and small objects.

Interviewee: I gave reasons for the importance of using a microscope.

"The use of a microscope, in my opinion, is essential because if there is no microscope, you cannot see/observe micro/tiny objects." (Interviewee I)

Interviewees who stated that microscopes are not critical argued that using microscopes is unimportant in everyday life. Interviewees argued that microscopes are essential in research and learning, such as studying cells and micro-objects.

"The use of microscopes, in my opinion, in everyday life is not too important, but for learning, microscopes are very helpful, especially when observing micro-objects, also when learning cells, where something difficult to see with the direct eye can be visualized with the help of the microscope." (Interviewee H)

Most of the interviewees' answers resulted in a statement that microscopes are essential in learning and researching micro-objects. This is related to using microscopes, which is learning biology. Considering that all interviewees are physics education students, using microscopes is less critical for physics learning. Microscopes are less significant for physics learning because the intensity of microscope use is less than in biology learning. The use of microscopes in physics is only limited to optical tools. Biology lessons usually use optical and electron microscopes to observe submicroscopic and microscopic components. The utilization of microscopes in learning biology is primarily due to observing biological objects such as cells and body tissues that are micro-sized

3. Viable Microscope

A total of 14 resource persons gave their opinions on appropriate microscopes. Some interviewees argued that a proper microscope is one that works according to its specific capabilities, namely being able to see tiny or micro-objects. Lens clarity and maximum magnification are also factors in microscope feasibility. Interviewee A gave an opinion about a proper microscope.

"A proper microscope is a microscope that can see objects that cannot be seen directly by the human eye. The particles or objects viewed must meet the capacity of the microscope." (Interviewee A)

The feasibility of the microscope is reviewed through the function of the lens that can see small objects so that they are visible in magnification. The standard lens used in microscopes is the achromatic lens. The feasibility of the microscope is affected by the magnification of the lens. The ocular lens of a microscope has a magnification of 10 times, while the objective lens with a zoom system has a magnification of 0.7 times to 3 times.

4. Microscope Price

A total of 14 interviewees gave opinions on the unaffordable price of microscopes as a problem in the daily use of microscopes. Most interviewees thought that the high cost of microscopes was a problem and that there was a need for more use of microscopes. Interviewees believed that the price of microscopes in the market could be more affordable for the general public. Interviewee W gave his opinion on the cost of microscopes.

"I think the price of the microscope is not very affordable." (Interviewee W)

The price of laboratory microscopes reviewed in online stores ranges from one million to three million. The price is not affordable for schools, especially public schools, resulting in a small number of microscope props available in schools. However, there are obstacles to learning this optical microscope tool because the number of microscopes in a school sometimes needs to be improved, requiring one microscope for many children at once.

5. Microscope Design Feasibility

A total of 14 resource persons gave opinions on the feasibility of microscope design. The majority of the 14 speakers gave the argument that the design of a simple microscope tool using the SolidWorks software program is feasible to use the design design. Feasibility is based on a relatively simple design. Another factor is that the items used are also easy to obtain, and the price is affordable. Interviewee V gave an opinion on the feasibility of microscope design.

"This microscope is worth using, especially if it is for small experiments, not for important research." (Interviewee V)

The design that uses surrounding materials affects the microscope manufacturing process to make it easier and more affordable. The implementation of objective and ocular lenses must meet the eligibility standards in the form of achromatic lenses. According to the standard with the ocular lens on the microscope, lens magnification is ten times, and the objective lens magnification is between 0.7 and 3 times. Manufacturing by the design plan produces a simple microscope with cheap materials. Given the expensive price of microscopes, a simple microscope design can be a solution.

6. Simple Microscope Design in Price Problem Solving

A total of 14 resource persons gave opinions on the design of simple microscopes as a solution to the high price of microscopes. The majority of the interviewees thought that a simple microscope design could be a solution to the high cost of laboratory microscopes. Interviewee M gave an opinion on the design of a simple microscope as a solution to the expensive price of microscopes.

"Simple microscopes can be an alternative solution for the general public who do not have access to more advanced and expensive microscopes. The public can access the microscopic world by using simple microscopes and learn more about invisible organisms and materials to the naked eye." (Interviewee M)

Implementing appropriate design materials allows for maximizing the product's usefulness as an alternative microscope. The limitations of these learning media and tools make finding alternative ways to replace conventional microscopes necessary. One of them is using a microscope with the help of a smartphone. As a learning media for cell observation, this simple microscope is included in the type of media by design.

A simple microscope using SolidWorks software can be an effective and affordable alternative. SolidWorks provides 3D visualization to view and manipulate the microscope model in three dimensions, enhancing students' understanding of its structure and function (Stricker, 2011). Project-based learning can integrate technical skills and problem-solving through practical design tasks (Silberman et al., 2012). Creativity and innovation development: Encouraging students to develop and implement new ideas in authentic designs (Kitrungloadjanaporn et al., 2018). Identifying needs and design specifications involves determining the main components of the microscope, such as lenses, tubes, bases, and focus mechanisms, and defining the size and materials to be used in the model construction.

Creating a 3D model involves using the microscope tube, lenses, and stand. Designing the main tube with extrude and cut features to make the lens hole. The revolve feature creates lenses from simple profile shapes (Perry et al., 2017). Creating a stable microscope base with extrude and fillet features adds strength and aesthetics. Simulation and Analysis are conducted to ensure the microscope's structural stability and optical function (Rabiu, 2017). The analysis feature checks stress and deformation on the main components. Teachers can use the 3D microscope model in class to explain the functions and parts of the microscope (Eswarappa Prameela et al., 2020).

They demonstrate how the microscope works using animations in SolidWorks—collaborative (Jovanovic & Jovanović, 2023) sign printed with a 3D printer in practicals. Designing a simple microscope using SolidWorks as an alternative learning media helps overcome school equipment's limitations and develops students' technical skills and creativity. By integrating CAD technology into science education, students can better understand complex concepts through practical and interactive approaches. This creates an innovative and enjoyable learning environment, ultimately enhancing the quality of science education in schools.

Conclusions

Referring to the research results conducted with interviews about the design of simple microscopes using Solidworks applications as an alternative learning media, it is feasible to use them as an alternative learning media. Designing a simple microscope using SolidWorks software offers an effective and affordable alternative for science education. SolidWorks' 3D visualization capabilities enhance students' understanding of microscope structure and function by allowing them to view and manipulate models. Project-based learning with SolidWorks integrates technical skills and problem-solving, fostering creativity and innovation. Students can create functional microscope models by identifying key components and utilizing SolidWorks' features for design and analysis. This approach not only overcomes equipment limitations in schools but also develops students' technical expertise and creativity, providing a practical and interactive learning environment that enhances the quality of science education

References

Aldoobie, N. (2015). ADDIE Model. *American International Journal of Contemporary Research*, *5*(6).

Anwar, Kholifah, Nurtanto, H. (2022). Journal of Technology and Science Education. *Journal of Technology and Science Education*, *4*(4), 215–227. http://www.jotse.org/index.php/jotse/article/view/110/142

Budi, Y., & Sukmono, T. (2023). Effectiveness of CAD-CAM Application for the Development design and implementation of maintenance tools. *Jurnal Penelitian Pendidikan IPA*, *9*, 671–680.

https://doi.org/10.29303/jppipa.v9i9.4859

de Menéndez, M., & Morales-Menendez, R. (2019). Technological innovations and practices in engineering education: a review. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *13*. https://doi.org/10.1007/s12008-019-00550-1

Eswarappa Prameela, S., Mcguiggan, P., Brusini, A., Glenn, T., & Weihs, T. (2020). Looking at education through the microscope. *Nature Reviews. Materials*, *5*, 1–3. https://doi.org/10.1038/s41578-020-00246-z

Jovanovic, J., & Jovanović, M. (2023). *The Solidworks Design Software in a Teaching and Workshop Mode for Creating Daily Products*. *71*, 17–20.

Kitrungloadjanaporn, P., Phothong, A., & Precharattana, M. (2018). Seesaw Balancing: A Hands-On Model to Understand Moment of Force in Classroom. *Applied Mechanics and Materials*, *879*. https://doi.org/10.4028/www.scientific.net/AMM.879.269

Melati, P. S., Prima, E. C., & Eliyawati, E. (2023). Android Game HUPROSED (Human Reproductive System and Sex Education) as Learning Media on Human Reproductive System Topic. *Journal of Science Learning*, *6*(3), 256–271. https://doi.org/10.17509/jsl.v6i3.45347

Novak, E. (2022). *3D Printing in Education*. https://doi.org/10.4324/9781138609877-REE81-1

OIKAWA, K., & Murakami, T. (2005). 216 Conceptual Design Education with 3D-CAD and Its Effect. *The Proceedings of the Technology and Society Conference*, *2005*, 105–108. https://doi.org/10.1299/jsmetsd.2005.105

Okolie, U., Mlanga, S., Oyerinde, D., Nathaniel, O., & Chucks, M. (2021). Collaborative learning and student engagement in practical skills acquisition. *Innovations in Education and Teaching International*, *59*, 1–10. https://doi.org/10.1080/14703297.2021.1929395

Perry, I., Szeto, J.-Y., D, I., Gealy, E., R, R., Scofield, S., D, W., & Hayes, A. (2017). *Production of 3D Printed Scale Models from Microscope Volume Datasets for use in STEM Education*.

Rabiu, A. (2017). *Application of Computer Aided Design and Drafting in Technology Education for Sustainable Development (Case Study of Kano State Higher Institutions)*. *1*, 69.

Saputra, D., Gürbüz, B., & Haryani, H. (2021). Android-based Animation for Chemical Elements and Experiments as an Interactive Learning Media. *J.Sci.Learn*, *2021*(2), 185–191. https://doi.org/10.17509/jsl.v4i2.28787

Seungoh Paek, D. L. H., & Black, J. B. (2023). Shaping the sensory experience in digital environments: modality, congruency, and learning. *Interactive Learning Environments*, *31*(9), 5665–5681. https://doi.org/10.1080/10494820.2021.2016860

Silberman, D., Rowe, S., Jo, J., & Dimas, D. (2012). *New teaching methods in use at UC Irvine Optical Engineering & Instrument Design Programs*. 03-. https://doi.org/10.1117/12.928814

Smith, R., Iversen, O., & Hjorth, M. (2015). Design thinking for digital fabrication in education. *International Journal of Child-Computer Interaction*, *5*. https://doi.org/10.1016/j.ijcci.2015.10.002

Stricker, D. (2011). A Case Study: Teaching Engineering Concepts in Science. *Center Studies*, *48*. https://doi.org/10.30707/JSTE48.2Sticker

Zhang, W. (2022). The Role of Technology-Based Education and Teacher Professional Development in English as a Foreign Language Classes. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.910315