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Development of Interactive Learning Media for Enhancing Computer Hardware Understanding in Multimedia Vocational Programs

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ABSTRACT

The rapid advancements in technology have positively influenced teaching and learning, particularly through Artificial Intelligence (AI) and Machine Learning (ML), which have significantly transformed educational processes. This study aims to design an interactive web-based learning media to enhance student engagement and understanding of computer hardware in the Computer and Basic Network subject for Grade X students in the Multimedia expertise program at a vocational high school. Utilizing the Richey and Klein Level 1 Research and Development (R&D) model, the study followed three stages: planning, production, and evaluation. This research addresses common challenges in teaching basic competencies such as applying and assembling computers, where many students lack foundational hardware knowledge. The developed media was validated by experts, resulting in a media feasibility score of 98.75% and a content accuracy score of 96.43%. Recommendations included defining clear learning outcomes, updating hardware specifications, and integrating evaluation tools—all of which were implemented. The final product was rated highly feasible and effective for classroom use.

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1. INTRODUCTION

Vocational High Schools (SMK) represent secondary education that prioritizes developing students' skills to enable them to directly engage in the workforce. The purpose of secondary education is to enhance knowledge, foster self-development in line with scientific advancements, and equip students with the ability to function as community members capable of reciprocal interaction. In accordance with regulations, vocational education emphasizes preparing students for employment while fostering professional attitudes (Indonesian Government Regulation No. 29 of 1990). Vocational High Schools offer various expertise programs tailored to industry demands, societal needs, market trends, and technological advancements (Sutiaharni, S., & Armiati, A. ,2020; Pratama, at al., 2019). These programs aim to equip students with the necessary skills and competencies for the workforce.

One such program is Multimedia, which has become increasingly essential over time. The Multimedia Expertise Program is designed to enhance skills in various media types, including text, audio, video, graphics, animation, special effects, and interactive media. This program is particularly relevant in the context of the 4.0 Industrial Revolution, where multimedia skills are in high demand (Thomas, et al., 2020). To effectively learn these media, supporting tools like computers/PCs are required. Students must first understand what a computer is and what components are needed to form a computer. Initial exposure to computers typically involves basic activities like typing, playing MP3 files, browsing the internet, displaying and editing photos, and watching movies (J. Com, 2011).

According to the Regulation of the Director General of Primary and Secondary Education No. 07 of 2018 on the Structure of Secondary Education Curricula for SMK (Vocational High School) and MAK (Madrasah Aliyah Kejuruan or Vocational Islamic Senior High School), the Multimedia Expertise Program includes understanding electronic media, including computers. Students learn about computer assembly, BIOS configuration, operating system installation, hardware driver and application software installation, and hardware maintenance and troubleshooting. These topics are essential for understanding how computers function and how to keep them running efficiently (Mao, L., Zhang, Y., & Li, R. 2020). These fundamental lessons serve as the cornerstone for more advanced topics. The urgency of addressing these issues is underscored by the increasing reliance on technology in vocational education. Interactive and adaptive learning tools, powered by advancements in AI and ML, offer promising solutions. These technologies enable personalized learning experiences, fostering deeper engagement and comprehension among students. By leveraging these innovations, this study aims to develop a ML-based web platform designed to enhance students' understanding of computer hardware. The platform's design and implementation align with the objectives of the Basic Computer and Network Systems curriculum, addressing identified gaps and paving the way for improved educational outcomes.

Based on the interviews with Grade X students at SMK Unggulan Terpadu PGII revealed challenges in Basic Competency 3.2, "Applying Computer Assembly." Teachers did not directly explain computer components; instead, they relied on images from textbooks or the internet. Many students struggled to understand these components, with some failing to recognize

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their physical forms or functions. This confusion led to frequent misidentifications of components. Such challenges underscore the need for teachers to employ creative and innovative teaching methods to ensure comprehension. Understanding hardware components thoroughly helps students troubleshoot technical problems effectively (J.Com, 2011). These components include both internal CPU elements and external devices connected to the computer (Bobi, 2014), all of which work interdependently to support the system's overall functionality. However, conventional instructional methods—such as relying solely on textbooks or static images—often fall short in helping students grasp the physical and functional aspects of computer hardware. These limitations emphasize the need for more engaging, student-centered instructional approaches that can bridge this learning gap.

In response to these challenges, the integration of modern technologies into educational practice has gained considerable attention. In this era of rapid technological advancement, education must align with current innovations to remain effective and relevant. Supplementing traditional lectures and printed materials with interactive digital tools offers significant potential to improve learning outcomes. Among these innovations, Artificial Intelligence (AI), particularly Machine Learning (ML), has emerged as a powerful tool to deliver personalized and adaptive learning experiences. Although relatively new in educational contexts, ML has demonstrated success in various fields and holds considerable promise for enhancing classroom instruction. Building on these insights, this study aims to design and develop a web-based learning platform powered by Machine Learning to support students' understanding of computer hardware. The platform specifically targets the Basic Computer and Network Systems subject for Grade X students in the Multimedia expertise program at vocational high schools, aligning with the curriculum and addressing identified pedagogical gaps.

2. METHODS

In this study, a design and development approach was used to develop a web based learning media platform exposing Grade X multimedia students to "Introduction to Hardware". The research process followed the Richey and Klein model, that includes three main stages: production, planning and evaluation. Before it got to the planning stage a needs analysis was undertaken through a review of literature, interviews, and field observation to understand challenges in teaching hardware concepts. Key issues reported by teachers were the lack of resources for teaching, inability to have hardware access and levels of student comprehension. There were difficulties, students reported, in identifying hardware components and getting an idea of their functions, as learning happened primarily through textbooks and online images.

The learning media platform was designed based on web technologies and machine learning algorithms in the production stage, it was integrated to personalize learners' experiences. Modules were developed using interactive explanations, quizzes and practical exercises so they addressed specific learning objectives. The media and the subject matter experts validated the evaluation stage. The feasibility and effectiveness of the platform were quantitatively analyzed using data from these validations. Through iterative refinement of the media, the results were used. Furthermore, the platform's technical performance was tested

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using Google Lighthouse for up to page performance, page experience, accessibility, best practice and SEO metrics. Descriptive quantitative analysis was employed to calculate scores and categorize the feasibility levels of the product.

3. RESULTS AND DISCUSSION

3.1. Planning Stage

During the planning stage, the researchers conducted a comprehensive literature review to gather research findings and information on computer hardware. Journals and books relevant to hardware concepts were analyzed to guide the development of the product. The researchers planned the development of a web-based learning media platform for the Basic Computer and Network Systems subject using machine learning. This platform aims to serve as an innovative educational tool for Grade X Multimedia students, enabling both teachers and students to learn collaboratively in class or independently. Needs analysis involved field research and literature studies, resulting in the identification of critical planning aspects, including:

1. Software Requirements Analysis
    a. Visual Studio Code: Used for creating and editing source codes in languages such as JavaScript, HTML, CSS, PHP, and Node.js to develop the web-based media platform.
    b. XAMPP: Utilized as an open-source web server to facilitate website creation.
    c. Google Chrome: Used as web browsers to run and test the website.
    d. Filezilla: Facilitated file uploads to hosting servers efficiently.
    e. Google Teachable Machine: Enabled machine learning integration through TensorFlow.js models for interactive educational features.
2. Hardware Requirements Analysis
   The hardware specifications required to develop and run the web-based learning media, including the software mentioned above, are as follows Table 1.

Table 1. Hardware Requirements Analysis

No	Hardware	Spesifikasi
1.	Processor	Intel Quad-Core
2.	RAM	2GB recommended 8GB
3.	Harddisk	800 MB – 210GB
4.	VGA	Resolution 720p
5.	Operating System	Windows 7/8/8.1/10

3. User Needs Analysis
   The platform is designed for accessibility via PC/Laptops or smartphones with an internet connection.
4. Curriculum and Content Planning

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The curriculum followed the 2013 curriculum standards, focusing on Basic Competency 3.2 "Applying Computer Assembly" and 4.2 "Assembling Computers." These competencies align with the subject syllabus for Basic Computer and Network Systems. Key objectives include understanding hardware components, determining hardware specifications, and conducting assembly procedures according to industry standards. The detailed competencies are shown in Table 2.

Table 2. Core Competencies (KI) and Basic Competencies (KD) 3.2 and 4.2

Core Competencies	
KI-3 (Knowledge)	Understand, apply, analyze, and evaluate factual, conceptual, procedural, and metacognitive knowledge relevant to the field and scope of Computer and Informatics Engineering at a technical, specific, detailed, and complex level. This involves integrating science, technology, arts, culture, and humanities within the context of personal development as part of family, school, workplace, and societal roles on a national, regional, and international scale.
KI-4 (Skills)	Perform specific tasks using tools, information, and work procedures commonly applied to solve simple problems in the field of Computer and Informatics Engineering. Demonstrate independent performance with measurable quality and quantity according to work competency standards. Show skills in reasoning, processing, and presenting ideas effectively, creatively, productively, critically, independently, collaboratively, communicatively, and solution-focused in abstract domains. Perform specific tasks under direct supervision while showing readiness, imitation, habituation, mastery, and original action in the concrete domain.
Basic Competencies	**Indicators of Achievement**
3.2 Apply Computer Assembly	3.2.1 Explain the parts of computer hardware 3.2.2 Determine computer specifications according to job requirements 3.2.3 Identify steps for assembling computers based on industry standards
4.2 Assemble Computers	4.2.1 Apply K3 (Occupational Safety and Health) procedures for computer assembly 4.2.2 Assemble computers according to industry standards 4.2.3 Create a report on computer assembly activities

These competencies and indicators provide a comprehensive framework for ensuring that students develop both theoretical and practical skills, aligning with the learning objectives of the Basic Computer and Network Systems curriculum.

5. Flowchart Development

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The initial stage in creating the media involved developing a flowchart. The purpose of this flowchart was to define the workflow or steps for using the media effectively. The following flowchart was designed by the researchers to outline the process of creating web-based learning media for introducing hardware concepts using machine learning. The explanation related to the flowchart can be seen in Figure 1, which outlines the structure and navigation of the web-based learning platform for computer hardware concepts.

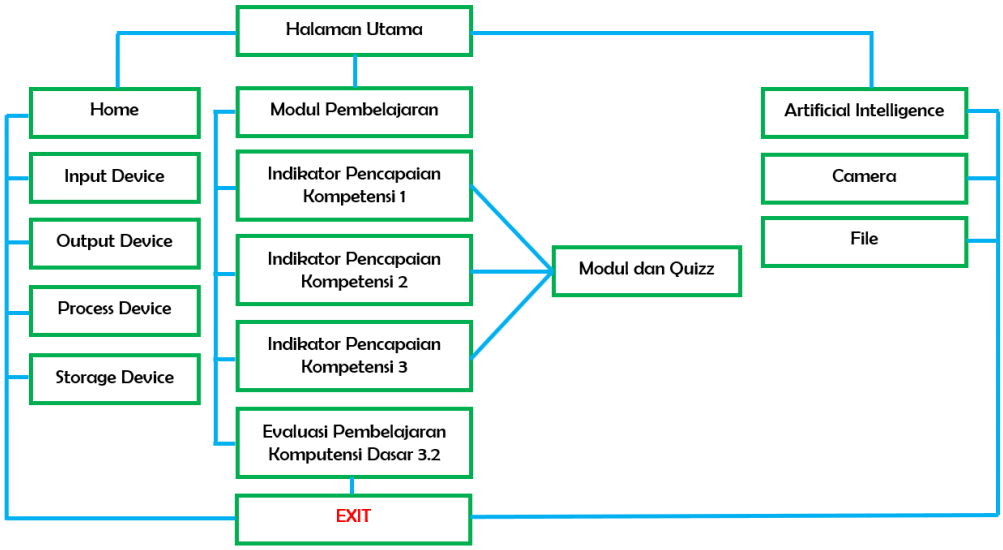

Figure 1. Flowchart of Web-Based Learning Media for Computer Hardware Introduction

The flowchart illustrates a structured and interactive web-based learning platform for teaching computer hardware concepts. The Main Page serves as the starting point, directing users to the home section, which provides detailed explanations of hardware components, including input, output, process, and storage devices. The Learning Module focuses on achieving specific competency indicators and includes an evaluation for Basic Competency 3.2, allowing students to assess their understanding. An Artificial Intelligence section enhances learning through tools like a camera and file access. The platform integrates modules and quizzes to reinforce knowledge, enabling students to learn interactively and systematically.

6. Wireframe Development

The next step after creating the flowchart for the web-based learning media is designing the wireframe, which serves as a blueprint for the media interface. Wireframe creation is a crucial stage in designing any media, as it visually organizes the interface elements and ensures functionality aligns with user needs. The wireframe design used in this study can be seen in Figure 2.

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Figure 2. Home Page Design

This page represents the main interface when users first access the web-based learning media. The home page features a moving image, often referred to as a slideshow, followed by various components that can be scanned, including input devices, output devices, process devices, and storage devices. Additionally, the page includes an embedded YouTube video related to Basic Competency 3.2. At the bottom of the page, a footer is present, completing the layout of this user-friendly and informative main page.

Figure 3. Design of the Scannable Component Feature Page

This page remains part of the home section and features interactive elements such as input devices, output devices, process devices, and storage devices, which can be clicked. Upon clicking one of these features, a pop-up appears displaying an illustration of the hardware component that can be scanned using the Artificial Intelligence section in the navigation bar. Users can only scan hardware components explained on this page, ensuring alignment with the provided descriptions. Not all components are scannable.

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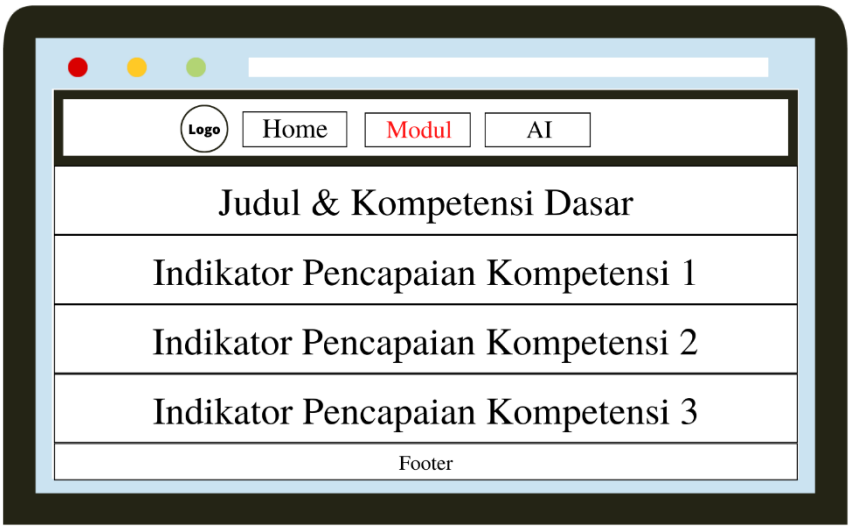

Figure 4. Design of the Learning Module Page

The learning module page contains the title and an explanation of Basic Competency 3.2. Below the title, the content continues with the learning module for Competency Indicator 3.2.1, followed by the modules for Competency Indicators 3.2.2 and 3.2.3, and concludes with the evaluation of Basic Competency 3.2. A consistent footer is displayed at the bottom of every page within the platform.

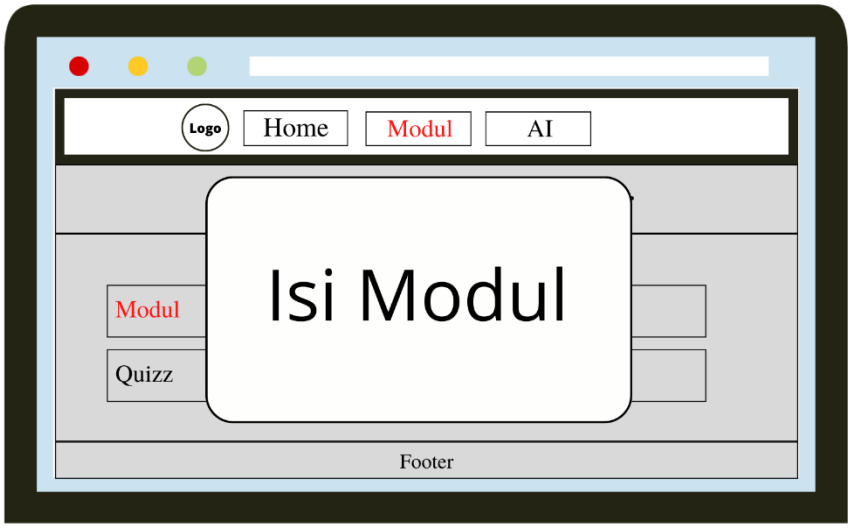

Figure 5. Design of Button Page in Competency Achievement Indicators

This page is part of the learning module section. The pop-up display appears when the user clicks on the Competency Achievement Indicator, specifically on the button for the learning module material. Within the Competency Achievement Indicator, there are two clickable buttons: one for the learning module material and another for the quiz. This design ensures easy navigation and access to relevant content and assessments.

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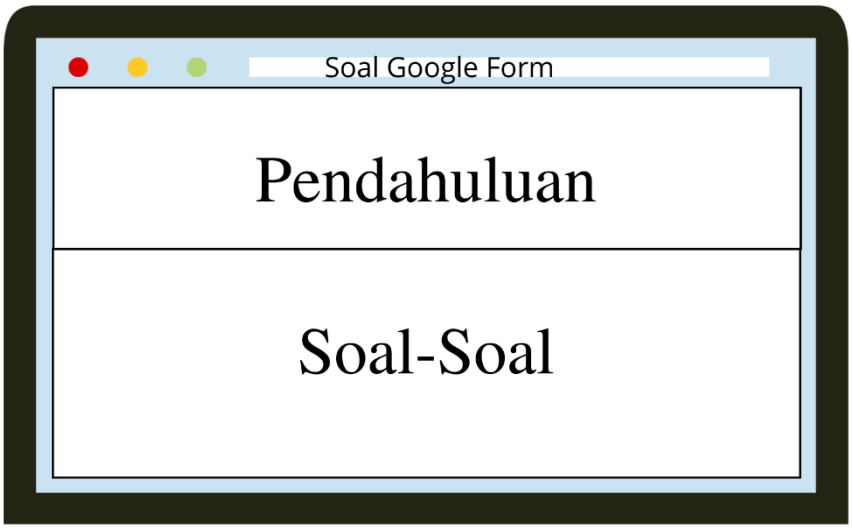

Figure 6. Design of the Quiz Button Page

This page appears when the user clicks on the "Quiz" button. Unlike the learning module page, this page is a separate hyperlink that redirects to the quiz. The page connects directly to a Google Form, allowing users to immediately work on the practice questions provided in the learning module. This integration ensures a seamless experience for accessing and completing quizzes.

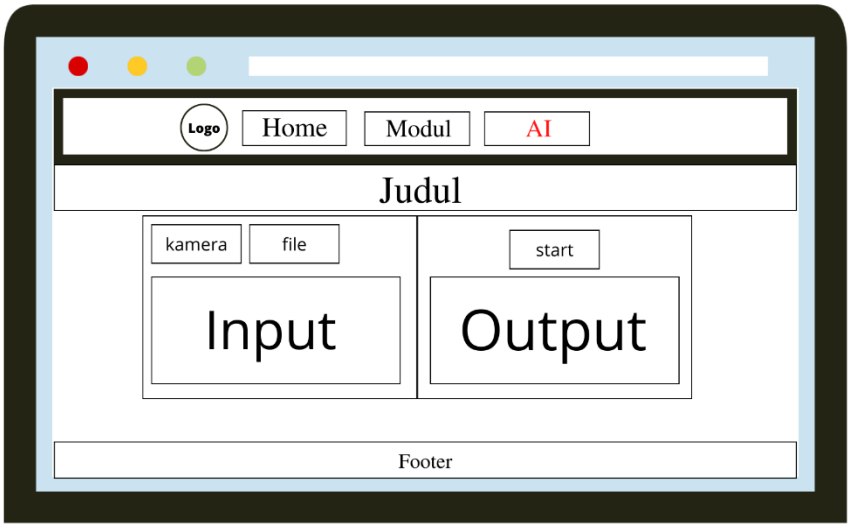

Figure 7. Design of the Artificial Intelligence Page

The Artificial Intelligence page is dedicated to hardware introduction learning using machine learning. It provides two feature options: Camera and File. Users can access these features by selecting one of the options.

a. Camera Feature: Users can scan hardware components using the camera. The website is compatible with smartphones and PCs/Laptops. On smartphones, users can choose between the front and rear cameras, while PCs/Laptops have a single camera automatically set up.

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b. File Feature: Users can upload images from their device storage (PC/Laptop or smartphone). Supported file formats include .png, .jpg, .jpeg, .webp, .jfif, and more. When an image is uploaded, the right side of the page displays the analysis result of the input image. Similarly, when using the camera, the right side of the page shows the output of the scanned hardware.

This design ensures flexibility and accessibility for learning through machine learning tools on multiple devices.

7. Color Concept
   The color concept for this media utilizes purple as the dominant color, complemented by three accent colors: pink, orange, and turquoise. The choice of purple symbolizes positive attributes such as luxury, imagination, inspiration, and richness. It conveys the idea that students in the multimedia expertise program are imaginative, inspiring, and capable of embracing the sophistication of multimedia. This color palette aligns with the nature of multimedia education, where students explore diverse media forms and prepare to adapt to advancements in technology and the ever-evolving multimedia industry. The accent colors (pink, orange, and turquoise) provide vibrancy and balance, enhancing the overall aesthetic appeal of the media.

8. Font Concept
   The font concept for this media uses the "Bookman Old Style" font-family as the primary typeface. This font is applied consistently across features, headers or navigation bars, footers, and the body of the website, ensuring readability and a professional appearance. For dynamic or moving images, additional fonts are used to enhance visual appeal, including HK Modular, Big Shoulders Display, and Bungee.
   a. Input Device Feature: Fonts Magz and Academy are used.
   b. Output Device Feature: Fonts Bungee and Academy are used.
   c. Process Device Feature: Fonts Val and Academy are applied.
   d. Storage Device Feature: Fonts Shrikhand and Academy are selected.

   This combination of fonts provides a modern and engaging aesthetic while maintaining functionality and accessibility for users.sdasd

The production stage involves the development of web-based learning media for the subject "Basic Computer and Network Systems" focused on hardware introduction using machine learning. This stage utilizes Visual Studio Code for media development and Google Teachable Machine for creating machine learning models. Before using Visual Studio Code, Apache in XAMPP must be activated. Below are the detailed steps for creating the web-based learning media:

1. Machine Learning Development
   The first step is to create the machine learning model using Google Teachable Machine:
   a. Define Classes: The researcher created 14 classes for the project, including Motherboard, Mouse, Keyboard, CPU, Hard Disk, SSD, RAM, VGA, Power Supply, Fan, Monitor, Headset, Speaker, not a Computer Component.

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b. Input Image Samples: Images were added to each class with various angles, shapes, and colors to improve detection accuracy. Each class contains 40–60 image samples sourced from the internet and directly photographed components.
c. Features in Teachable Machine: Upload images from Google Drive or files on a PC/Laptop and capture images directly using a webcam.

2. Media Design
After completing the machine learning model, the next step is designing the web-based learning media:
a. Framework Setup: CodeIgniter 3 was downloaded and used as the framework to simplify coding in PHP. The framework was stored in the htdocs directory of XAMPP to enable running the media on a web browser.
b. Development with MVC: The project used the Model-View-Controller (MVC) concept to separate data processing (Model), user interface manipulation (Controller), and presentation (View). This structure enhances security and modularity, enabling better organization of files for database management, views, and controllers.
c. Implementation in Visual Studio Code: The coding process for the media interface and machine learning integration was completed using Visual Studio Code.

By following these steps, the media development process ensures functionality, user-friendliness, and effective learning outcomes for students. After setting up CodeIgniter, the next step was designing the interface using Bootstrap. Bootstrap simplifies the website development process by serving as a more user-friendly alternative to CSS. It is a framework for HTML, CSS, and JavaScript that enables quick and easy design of responsive websites. While Bootstrap operates on the front-end, CodeIgniter functions on the back-end, making them complementary technologies. Bootstrap focuses on creating visually appealing and responsive interfaces, while CodeIgniter handles data processing and server-side functionality, ensuring a seamless integration of the two frameworks. Once both CodeIgniter and Bootstrap were ready, the technical development of the application commenced using Visual Studio Code. Known as a powerful code editor, Visual Studio Code supports application development through efficient coding techniques, providing the tools needed to implement both the back-end and front-end elements of the web-based learning media.

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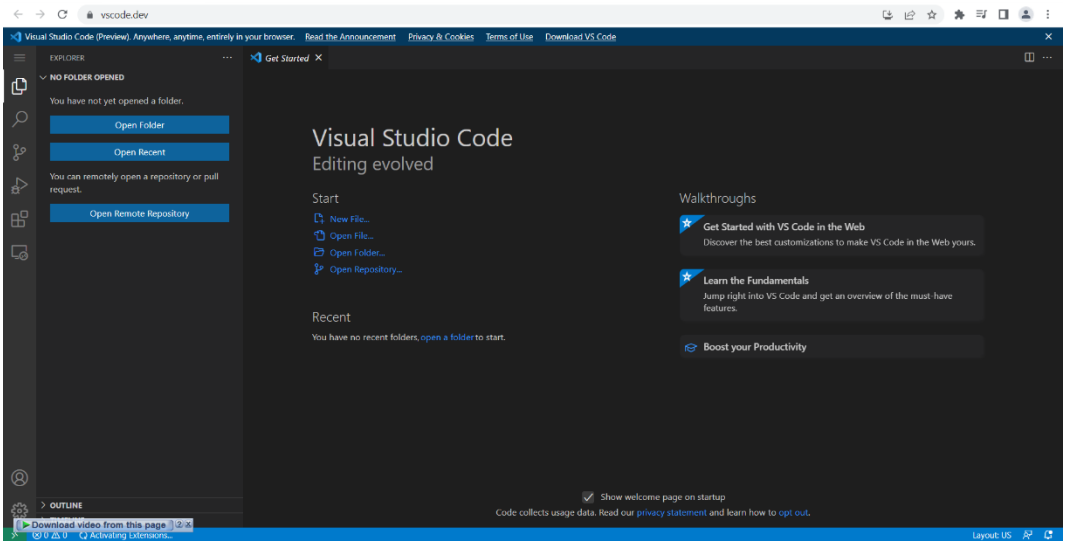

Figure 8. Initial Screen of Visual Studio Code

Programming languages like PHP and JavaScript require a web server to execute the code. In this study, the researcher used XAMPP to activate the Apache server, enabling the execution of PHP and JavaScript codes. This activation is essential because these programming languages cannot run directly in a web browser. Unlike HTML, which can run directly in a browser as it is a markup language, PHP and JavaScript are programming languages that depend on a server-side environment for execution. The use of Visual Studio Code as a code editor, combined with XAMPP as the web server, ensures a seamless development environment for the web-based learning media.

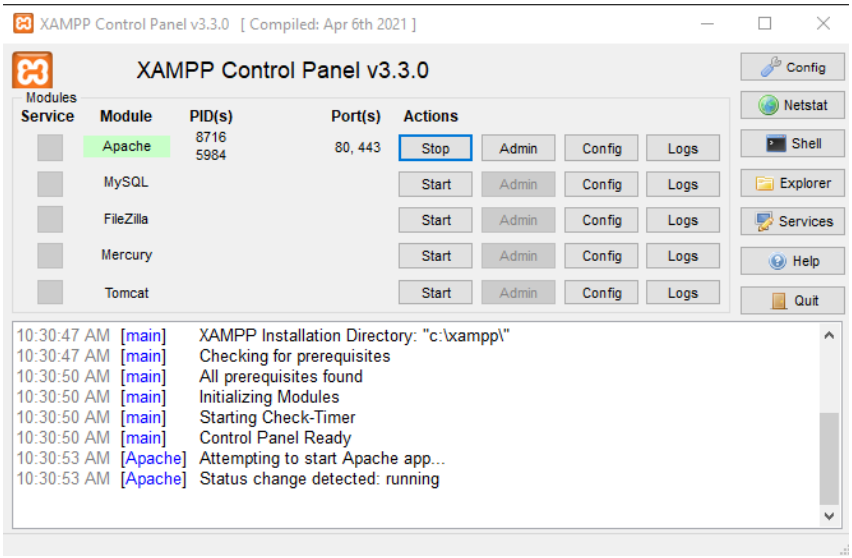

Figure 9. Activating Apache in XAMPP

Activating Apache is necessary to run PHP and JavaScript based programs. Apache is the web server, executing the server-side scripts and use the web applications. It is a step to make sure that the development environment is completely up and running,

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for integration and test of the web-based learning media. Using these in combination with the integration of Visual Studio Code, CodeIgniter and Bootstrap creates a robust development environment. The result is that PHP and JavaScript programming can be simultaneously and efficiently embedded into the design of interactive and responsive learning media. By having set such tools and configurations, the system is ready to offer the best user experience and make it compatible to achieve the educational goals.

3. Product Review
   The result of developing a web-based learning media for hardware introduction in the multimedia expertise program at SMK is an online website hosted at https://sekarnurulfa.my.id/. Below are the outcomes of the product development process:
   a. Home Page
      The main interface is the home page that contains a carousel slide or slideshow with information about the "Basic Computer and Network Systems" subject, a hardware introduction and AI-based learning media. The carousel slide was created using HTML integrated with Bootstrap classes, providing a dynamic display of moving images. Additionally, the home page includes modal components and embedded YouTube content. The modal displays illustrations of hardware components that can be scanned, enhancing interactivity.
   b. Learning Module Page
      This page contains the learning materials for the "Basic Computer and Network Systems" subject, focusing on Basic Competencies 3.2 (Applying Computer Assembly) and 4.2 (Assembling Computers). It presents objectives, basic competencies, competency indicators, and learning materials. To display .pdf files, the modal was customized to create a transparent appearance, emphasizing the learning content. The page includes buttons for accessing materials and quizzes. The material button activates a normal modal containing the content, which can be further customized.
   c. Artificial Intelligence Page
      This page is the core of the learning media, focusing on back-end JavaScript integration. The JavaScript connects the Google Teachable Machine with the developed media, importing classes from the Teachable Machine and matching user inputs with the model using logical operators. The page allows users to select between two input methods: camera or file. For camera input, users can choose a front or rear camera on smartphones or a default camera on PCs. The "Start" button activates live camera mode, enabling users to scan hardware components. A red pause button in the top-right corner allows users to pause the camera and freeze the output.

Media validation was conducted by a lecturer from the Software Engineering Study Program at UPI Cibiru Campus. The results were calculated using the formula:

$$P = \frac{x}{n} \times 100\% = \frac{79}{80} \times 100\% = 98.75\%$$

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The evaluation covered aspects such as learnability, efficiency, delight, and system performance, resulting in a score of 98.75%, categorized as "very high." It can be concluded that the web-based learning media for hardware introduction using machine learning is highly suitable for use without revision.

Material validation was conducted by a teacher of the "Basic Computer and Network Systems" subject. The results were calculated using the formula:

$$P = \frac{x}{n} \times 100\% = \frac{54}{56} \times 100\% = 96.43\%$$

The evaluation focused on aspects such as self-instruction, self-contained, adaptive, and user-friendly features, resulting in a score of 96.43%, which falls into the "high" category. However, some minor revisions were recommended regarding the content of the learning module:

1. The final learning outcomes for each indicator should be explained in more detail.
2. The content in the module should align with the current minimum computer specifications.
3. All quizzes and evaluations should include a grading system.

The researcher implemented the revisions based on the feedback and suggestions provided by the material expert. It can be concluded that the web-based learning media for hardware introduction using machine learning is categorized as highly suitable for use.

4. CONCLUSION

This study developed a web-based learning media to support the introduction of computer hardware concepts for Grade X students in the Multimedia expertise program at vocational schools. The media was designed to address students' difficulties in understanding foundational hardware components, which are crucial for mastering advanced competencies such as computer assembly. Following a three-stage Research and Development process—Planning, Production, and Evaluation—the platform integrated machine learning features, interactive modules, and accessible user interfaces. Validation results confirmed the media's high feasibility and accuracy, with minor refinements implemented to enhance content alignment and clarity. Performance evaluations using Google Lighthouse also verified the media's optimal functionality, accessibility, and SEO performance, contributing to an effective and user-friendly learning experience. These findings indicate that the developed media is not only a viable solution for teaching complex hardware concepts but also fills an existing gap in vocational learning resources. For future research, it is recommended to expand the implementation across various vocational schools and explore the integration of real-time student analytics to further personalize learning experiences. Longitudinal studies may also be conducted to assess the media's long-term impact on student competence and engagement in hardware-related subjects.

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AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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