Original Research Article

Architecture Design of Internet of Things Virtual Laboratory

ABSTRACT

The development of the internet today has been very developed including for the world of education, one of the technologies is the application of the Internet of Things (IoT) which should be accompanied by an increase in student competence in higher education but is currently still constrained by laboratory facilities, The purpose of this study is to produce an IoT virtual laboratory architecture design, which will then be developed into an IoT virtual lab system. The method used in this research is the waterfall method in the design and design aspects, testing is done using an expert validation instrument to determine the validity level of the virtual laboratory design before entering the implementation or system creation stage. The research has produced an IoT virtual laboratory architecture consisting of three main components, namely (1) virtualab information system, (2) virtual lab manager and (3) system integration through SCORM (Sharable Content Object Reference Model) which is used for integration into the LMS (Learning Management System) system, the results of validation from experts on the design of the IoT virtual laboratory architecture show an average score of 3.56, within the value range of 3.26 to 4.00. This indicates a very good level of quality. This indicates a very good level of quality. However, there are still areas that need to be improved, especially in criterion V2 related to the system development flow diagram which gets an average score of 3.33, so the results of this research design can be used for the system development stage.

Keywords:*Virtual Laboratory, Internet of Things, Waterfalls*

INTRODUCTION

The advent of information and communication technology has revolutionized human existence by establishing direct internet connectivity. This has led to significant advancements in various sectors including industry, agriculture, fisheries and marine, health, economy, and education. Particularly in the field of education, a profound understanding and proficiency in internet-related matters have become increasingly crucial. A study has unveiled that the industry today and in the future requires a minimum of three essential areas of expertise, namely: Artificial Intelligence (AI), Internet of Things (IoT), and Edge Computing (EC). (Dec et al., 2022)Comma The rapid advancement of technology and information has created a significant need for the implementation of the Internet of Things (IoT) both presently and in the future.

The need for IoT laboratories is indirectly increasing due to the existing requirement of IoT courses in many educational institutions. Presently, educational establishments ought to develop IoT curricula, provide training sessions and courses, and offer learning platforms in virtual environments. (Alharbi, 2020) (Dec et al., 2022). Utilizing simulators and virtual laboratories, the application of Internet of Things (IoT)-based technologies can facilitate innovation in practical learning models. (Martin, 2021a; Sabran, Purnamawati, 2020a) emphasize the need of exploring the utilization of the Internet of Things (IoT) in education, both presently and in the coming years.

The IoT practical learning system necessitates the incorporation of several systems rather than relying solely on a single major component (Budai and Kuczmann, 2018). Hence, there is a requirement for a system that is interconnected with several applications such as Learning Management System (LMS), simulator, video conferencing, and Massive Open Online Courses (MOOCs) (Ballu et al., 2016; Stark et al., 2018). To proactively prepare for forthcoming changes, it is necessary to implement a transition in online learning that specifically emphasizes the development of skills. Studies on the deployment of virtual laboratories indicate that virtual laboratories can enhance learners' engagement in practical activities, even in online settings, serving as a viable substitute for physical laboratories. The citation is from Radhamani et al. (2021). Virtual practicum can serve as a substitute for the instructor's theoretical instruction prior to engaging in practical activities in the physical laboratory. The aforementioned strategy has the capability to offer a comprehensive

assessment of practicum materials and student accomplishment levels, comparable to conventional ways, while simultaneously enhancing students' cognitive abilities (Widowati et al., 2017).
Multiple research on virtual learning demonstrate that virtual learning is at least equivalent to traditional face-to-face learning, and may significantly enhance learners' abilities. The references cited are Hamed and Aljanazrah (2020) and Bortnik et al. (2017). Virtual laboratories enhance students' practical abilities through an inquiry-based learning environment and increased adaptability. The utilization of virtual laboratories can persist after the conclusion of the pandemic, as there has been a digital metamorphosis in educational learning, encompassing the practicum procedure.
The implementation of the LAVIR (virtual laboratory) model by vocational students in research can enhance the development of students' life skills. (Haryoko and Jaya, 2018). Evidence from research on virtual laboratories indicates that students' attitudes during practicum utilizing virtual laboratories are comparable to those observed during practicum conducted in real laboratories. The reference is from Ratamun and Osman's publication in 2018. Conducting practical training can enhance students' enthusiasm to learn, particularly when accompanied by dynamic and informative practical training materials (Palerangi et al., 2015; Hao et al., 2021).
In a study conducted by Tamas Budai et al. in 2018, titled "Towards a modern, integrated virtual laboratory system," the researchers present an overview of virtual and remote laboratory systems. The study aims to evaluate current solutions that focus on practicality and use in higher education. Virtual laboratories provide a secure environment for students to carry out experiments. They also have the capability to replicate challenging conditions, such as alterations in gravity or exceptionally high temperatures, that would be impractical or costly to recreate in conventional or remote laboratories (Budai &Kuczmann, 2018). The new system must possess the capability to seamlessly interface with a widely adopted Learning Management System, such as Moodle. Laboratory Managers should utilize the LMS (Learning Management System) to verify and grant access to teachers and students, as depicted in Figure 1 of the virtual laboratory design.

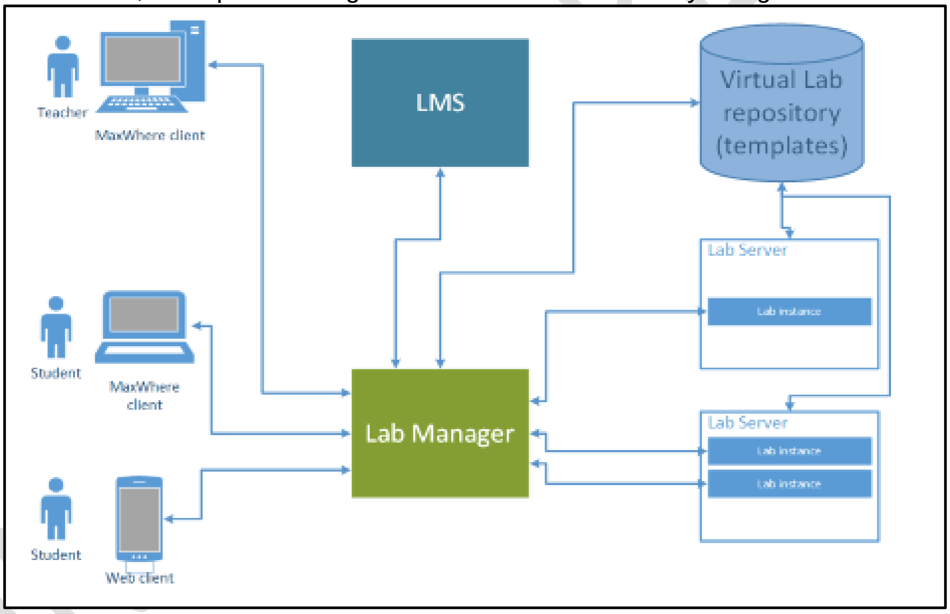

Figure 1. High level architecture of the virtual laboratory framework (Budai &Kuczmann, 2018)

Based on the problem background and previous research, it is evident that an IoT laboratory is crucial for learning IoT courses. However, some campuses lack the resources to establish such a laboratory. As a result, virtual laboratory solutions have emerged as an alternative. Therefore, there is a need to design an Internet of Things virtual laboratory to address the current changes and challenges. This study aims to develop a virtual laboratory system, focusing on the design stages of the Internet of Things virtual laboratory development flow and IoT virtual laboratory architecture.

METHOD

This study employs the Research and Development approach by incorporating the Waterfall development model. The model commence with a needs analysis, followed by system design and development through the creation of programs and program units. Subsequently, the developed applications are integrated and implemented, and the system undergoes rigorous testing. The process concludes with the implementation and maintenance stages, as depicted in Figure 2 (Alshayeb et al., 2018; Lewis, 2022).

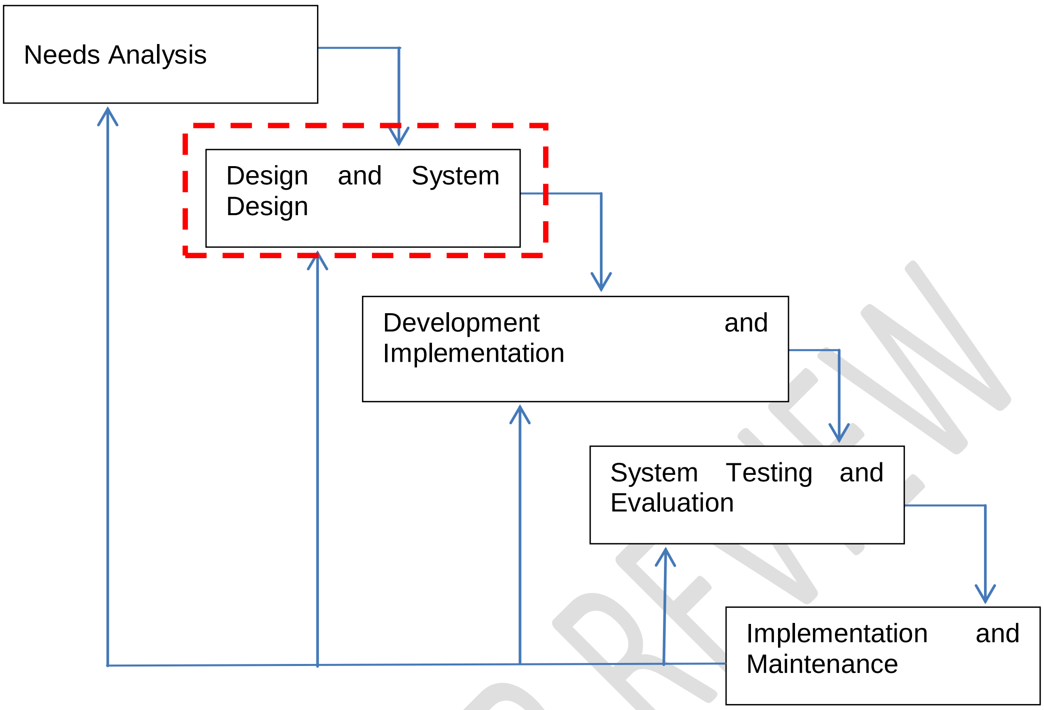

Figure 2. Waterfall Development Model (Pressman, 2010)

The Waterfall method is part of the Research and Development method or known as the Research and Development (R & D) method, which is a research approach to produce a new product or improve existing products. According to Sugiyono (2009: 407) the R & D method is a research method used to produce a certain product and test a product. this research method produces a product in a certain field of expertise, which has the effectiveness of a product (Saputro, 2017).
This waterfall model is executed sequentially where the output of one phase is the same as the input for another phase. Each phase must be completed before proceeding to the next phase (Petersen et al., 2009; Magnus et al., 2022), The stages of the waterfall model software development method can be described as follows:

1. Examination The first phase of software development requirements, known as needs gathering, is conducted with great focus and precision to gain a thorough understanding of the exact sort of software desired by users. Documentation of software requirement specifications is mandatory.
2. Software design is a complex process that involves generating a design for a software program. This includes defining data structures, software architecture, interface representations, and coding techniques. The process begins with the translation of software requirements from the requirement analysis stage into a design representation, which may then be implemented into a program.
3. The program code needs to be converted into a software program, resulting in a computer program that aligns with the design created in the design stage.
4. The testing phase is dedicated to evaluating the functionality of the system to verify that all components have undergone thorough testing. This is done in order to minimize errors.
5. During the Maintenance and Implementation Stage, which marks the end of the waterfall technique, it is possible for defects that were not found during testing to arise or for the program to need adjustments to function in a new environment (Lewis, 2022; Voutama and Novalia, 2022).

This research focuses on the Design stage of the waterfall model. During this stage, researchers develop software program designs, including the architecture of the Internet of Things laboratory. These designs are then validated by specialists in the validation step.

Table 1. Architecture design of Internet of things laboratory

Waterfall Stages	Process	Output
Architecture Design of IoT Virtual Lab	Developing a Virtual Lab Architecture	Architectural Design

Table 2. IoT virtual laboratory architecture design validation instrument

ID	Questions
V1	The design of the IoT virtual laboratory development block diagram is appropriate and describes all aspects of development.
V2	The design of the system development flow diagram design is well displayed.
V3	The design of the design and development of the system is well displayed.

The formula used is a descriptive analysis technique with an average scoring of answers to each item assessed (Arikunto, 2006). As follows:

$$P = \frac{\Sigma x}{n} \qquad (3.2)$$

Description:
P = average scoring
$\sum x$ = the number of answers of each respondent from each item assessed
n = number of respondents

Table 3. Mean score criteria

Score	Description
3,26-4,00	strongly agree / very good / very available / very ever
2,51-3,25	agree / good / available / ever
1,76-2,50	less agree / less good / less available / less ever
1,00-1,75	disagree / not good / not available / never

RESULTS AND DISCUSSION

System Design and Design

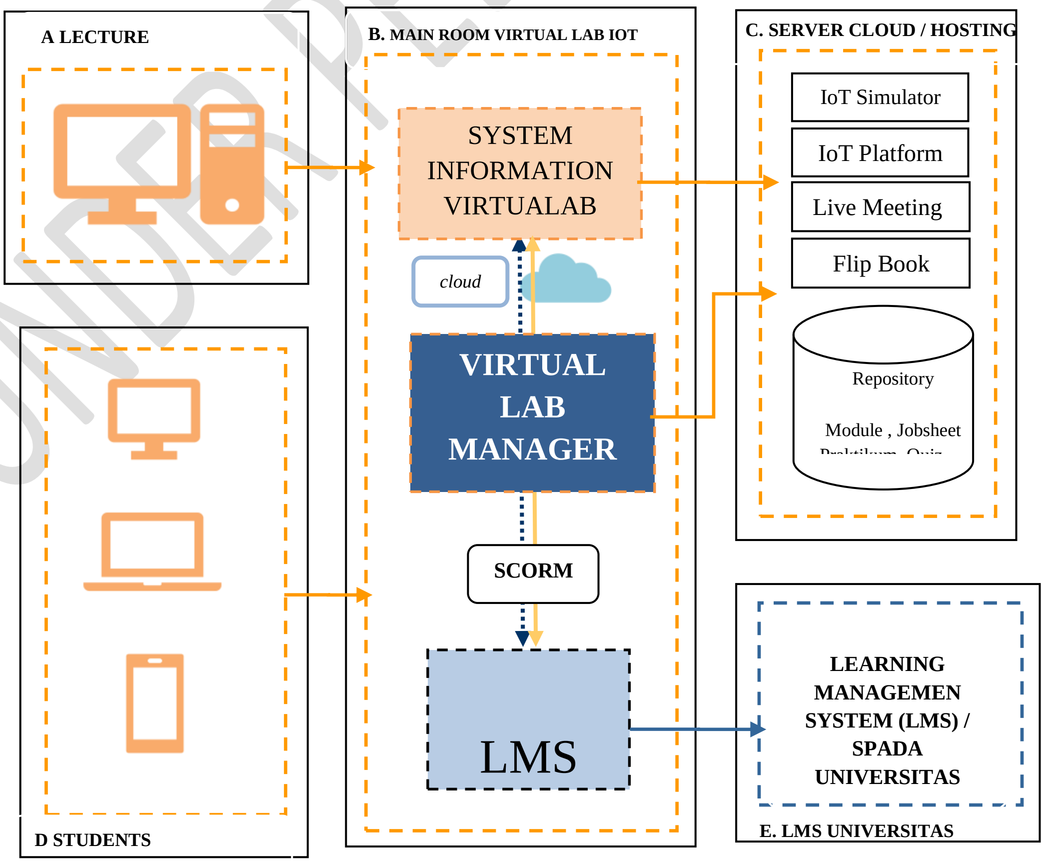

Figure 3. IoT Virtual Lab Architecture Design

The process of developing a virtual laboratory system for the Internet of Things (IoT) starts with establishing comprehensive virtual laboratory architecture. The architecture is constructed upon the findings of a comprehensive analysis of the prevailing conditions, challenges, and available resources, as well as several relevant references pertaining to the advancement of virtual laboratories. This culminates in the establishment of fundamental virtual laboratory architecture, as seen in Figure 3.

The Lab Virtual Manager serves as the central component of the IoT virtual laboratory architecture. It functions as the main room of the virtual laboratory. Additionally, SCORM facilities are utilized for seamless integration into the LMS system. Both lecturers and students have access to the main room and the LMS, which have been integrated with the virtual lab system. The system also offers IoT Simulator services, an IoT Platform, Live Meeting functionality, and Flipbook capabilities. These services are hosted on cloud servers and utilize cloud resources. The hosting includes a Module repository, Practicum Jobsheet, Quiz, Multimedia, and Assessment features.

The integration of the virtual lab system relies on the utilization of the SCORM (Sharable Content Object Reference Model) package. This package is obtained through the information system and subsequently installed on the University's SPADA system. To enable integration, it is necessary to have a system that supports the use of SCORM packages, such as Moodle LMS. Once the integration is established, all functionalities of the virtual lab, including simulators and assessments, can be accessed and utilized on the University's LMS. Additionally, there is a system log available that can serve as an assessment tool for lecturers.

System Design Expert Validation

An evaluation is needed to determine the practicality of creating an IoT virtual laboratory design using three primary instruments. These instruments include: (1) A suitable block diagram that encompasses all aspects of the development of the IoT virtual laboratory design, and (2) A properly displayed system development flow diagram. The system's design and development have been adequately shown. The instrument is evaluated by three experienced responders in the field of web programming design and layout. The analysis results based on the criteria are as follows.

Table 4. Analysis Results of IoT virtual laboratory Architecture Design Validation Instrument

Category	**Architecture Design Validation of IoT virtual laboratory**			**Average score**	**Score**
	V1	**V2**	**V3**		
Mean	4	3	4	3,67	91,66667
Std.deviation	0,58	0,58	0,58	0,58	12,73
Average	3,67	3,33	3,67	3,56	88,89
Percentage Gain P = (Σx / N) x 100%					88,89

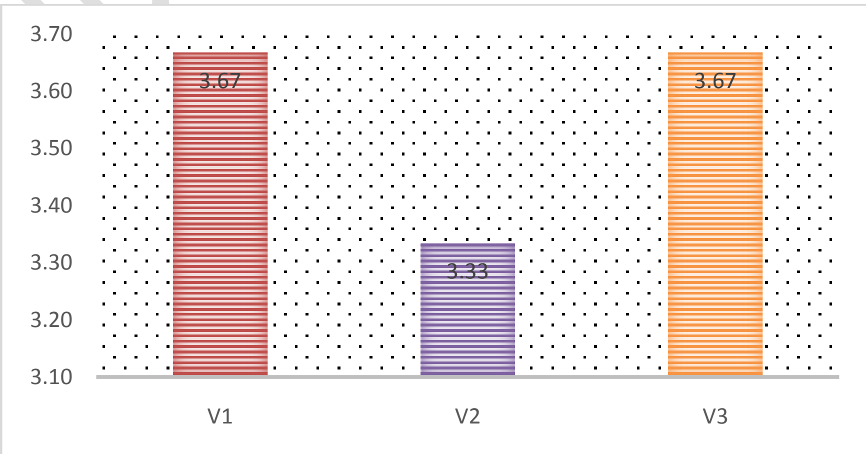

Figure 4. Graph of IoT virtual laboratory architecture design analysis results

Description:

V1: The block diagram design of the IoT virtual laboratory development is appropriate and describes all aspects of the development.
V2: The design of the system development flow diagram design is well displayed.
V3: The design of the design and development of the system is well displayed.

The achieved findings of the design and development of the Internet of Things (IoT) virtual laboratory system commence with the creation of a general virtual laboratory architecture. The architecture is constructed by incorporating findings from prior research and referencing various factors such as conditions, issues, and available resources. It also draws upon multiple sources related to the advancement of virtual laboratories. As a result, the fundamental architecture of virtual laboratories is established, aligning with the core concept and expanding upon the virtual lab framework proposed by Budai and Kuczmann (2018). This framework encompasses a high-level architecture that leverages Lab Manager, repository, and cloud hosting.

Laboratory Virtual Manager serves as the overarching framework for the IoT virtual laboratory architecture. The Lab Virtual Manager functions as the central hub of the virtual laboratory. Additionally, there is a display interface that can be openly accessed through the virtual information system. The virtual lab manager has the capability to generate a system package known as SCORM (Sharable Content Object Reference Model). SCORM is a protocol used in learning management systems to facilitate communication between different systems. This standard establishes a communication protocol and data structure that enables seamless collaboration between eLearning content and LMS (Jones, 2022). SCORM is extensively employed in higher education settings by instructors (Valieiev, 2023). Through integration with the virtualab system, students can access the primary room and LMS, which offer a range of services such as IoT Simulator, IoT Platform, Live Meeting, and Flipbook. These services utilize cloud server resources and hosting, including Module repository, Practicum Jobshet, Quiz, Multimedia, and Assessment.

An IoT simulator feature is a software or application that is specifically built to replicate an IoT environment. This environment allows connected devices to digitally communicate with each other and with the system. The purpose of IoT simulation is to facilitate developers, researchers, and other users in testing, developing, and validating IoT solutions without the requirement of using real physical hardware. Simulators can be utilized to offer practical experience and enhance students' abstract and critical thinking abilities without the potential hazards associated with using physical devices (Aisyah et al., 2023).

This virtual laboratory employs the IoT Platform, a software framework that offers a range of services and capabilities required for the management, connectivity, and analysis of data from IoT devices. This platform serves as a middleman between interconnected simulator devices and apps or services that utilize data from these devices (Muttaqin et al., 2023).

Live meetings are utilized for practical activities learning in a synchronous or online manner to facilitate the operation of a virtual laboratory in both online and offline settings. The architectural design incorporates a flipbook that serves the purpose of showcasing guidebooks, introductory books on IoT, modules, and jobsheets in a more engaging manner.

The IoT virtual lab contains a collection of Modules, Practicum Jobsheets, Quiz, Multimedia, and Assessment functions. These learning resources can be stored, displayed, and updated as necessary. To integrate with LMS or SPADA colleges, the SCORM method is employed. This involves uploading or integrating with LMS platforms such as Moodle in universities (Valieiev, 2023).

The expert validation examination of the architectural design of the IoT virtual laboratory yielded an average score of 3.56 within the range of 3.26 - 4.00. This indicates that the architectural design is highly commendable, however there is still room for improvement. Criterion V2 The system development flow diagram design has been effectively presented with an average score of 3.33. Expert validators have provided input regarding the architectural design of the IoT virtual laboratory. Specifically, they suggest including detailed information about cloud resources and hosting in the section related to section information, as the presence of internet resources is crucial in this architecture. Based on this input, the researcher has made enhancements by adding information to the cloud image section. The utilization of hosting and cloud for virtual labs can enhance the performance of the web system (Ramamurthy et al., 2020).

CONCLUSION

The research has developed an architectural design for the Internet of Things (IoT) virtual laboratory. The validation results from experts on the architectural design of the IoT virtual laboratory indicate an average score of 3.56, falling within the range of values from 3.26 to 4.00. This signifies a commendable standard of excellence in the realm of Architectural Design. Nevertheless, there are specific aspects that require enhancement, particularly in criteria V2 pertaining to the flow diagram of system development, which receives an average rating of 3.33. Architecture is constructed through a comprehensive analysis of conditions, issues, and available resources, as well as other references pertaining to the advancement of virtual laboratories. Architecture is constructed using the findings of a conditions analysis. The IoT virtual lab contains a collection of Modules, Practicum Jobsheets, Quiz, Multimedia, and Assessment functions. These resources can be stored and displayed, and can be updated as necessary. To integrate with LMS or SPADA colleges, the SCORM method is employed. This involves uploading or integrating with LMS platforms such as Moodle in colleges.

REFERENCES

Aisyah, N., Suparman, S., Suhaimi, L., 2023. The Effect of Using a Virtual Laboratory Assisted with PHET Media on Students' Creative Thinking Skills in Dynamic Electrical Material. JIIP-Scientific Journal of Educational Sciences 6, 1225–1231.

Alharbi, F., 2020. Integrating internet of things in electrical engineering education. International Journal of Electrical Engineering Education 1–18. https://doi.org/10.1177/0020720920903422

Alshayeb, M., Mahmood, S., Aljasser, K., 2018. Moving from Waterfall to Agile Process in Software Engineering Capstone Projects 107–114. https://doi.org/10.5121/csit.2018.80808

Ballu, A., Yan, X., Blanchard, A., Clet, T., Mouton, S., Niandou, H., 2016. Virtual Metrology Laboratory for e-Learning. Procedia CIRP 43, 148–153. https://doi.org/10.1016/j.procir.2016.02.110

Bortnik, B., Stozhko, N., Pervukhina, I., Tchernysheva, A., Belysheva, G., 2017. Effect of virtual analytical chemistry laboratory on enhancing student research skills and practices. Research in Learning Technology 25, 1–20. https://doi.org/10.25304/rlt.v25.1968

Budai, T., Kuczmann, M., 2018. Towards a modern, integrated virtual laboratory system. Acta Polytechnica Hungary 15, 191–204. https://doi.org/10.12700/APH.15.3.2018.3.11

Dec, G., Stadnicka, D., Paśko, Ł., Mądziel, M., Figliè, R., Mazzei, D., Tyrovolas, M., Stylios, C., Navarro, J., Solé-Beteta, X ., 2022. Role of Academics in Transferring Knowledge and Skills on Artificial Intelligence, Internet of Things and Edge Computing. Sensors 22. https://doi.org/10.3390/s22072496

Hamed, G., Aljanazrah, A., 2020. the Effectiveness of Using Virtual Experiments on Students' Learning in the General Physics Lab. Journal of Information Technology Education: Research 19, 977–996. https://doi.org/10.28945/4668

Hao, C., Zheng, A., Wang, Y., 2021. future internet Experiment Information System Based on an Online Virtual Laboratory. https://doi.org/10.3390/fi13020027

Haryoko, S., Jaya, H., 2018. the Role of Multimedia Technology (Lavir-Virtual Laboratory) in Developing Life Skills in Vocational Schools. MATTER: International Journal of Science and Technology 4, 143–154. https://doi.org/10.20319/mijst.2018.41.143154

Jones, E.R., 2022. Implications of SCORM and emerging e-learning standards on engineering education, in: 2002 GSW.

Lewis, S., 2022. What is the waterfall model? - Definition from WhatIs.com [WWW Document]. URL https://www.techtarget.com/searchsoftwarequality/definition/waterfall-model (accessed 8.10.22).

Magnus, A., Mekeng, R., Informatia, P.J.J., Asia, U.S., Rm, J.L.H., Minggu, P., Selatan, J., 2022. Design of an Internet of Things Based Watering System in Dry Land Agriculture Using the Waterfall Model. Journal of Cyber Science 1, 39–43.

Martin, S., 2021. Internet of Things Learning and Teaching. https://doi.org/10.3390/technologies9010007

Muttaqin, Janner Simarmata, Mohamad Arif Suryawan Jovi Antares, Muh. NadzirinAnshari Nur, Ilham Firman Ashari Oktoverano, Hendrik Lengkong, Harizahayu, Markani Pato Ade Maulana, Nurzaenab, M.H.A., Ery Murniyasih Muhammad Akram Hamzah, Muhammad Resha, Andryanto., 2023. Internet of Things (IoT): Theory and Implementation. We Write Foundation, Medan.

Palerangi, A.M., Baharuddin, F.R., Amirudin, 2015. Contribution of practical work implementation and learning motivation to vocational school students' practical work results. … Technology, Vocational, and … 38, 167–176.

Petersen, K., Wohlin, C., Read, D., 2009. The waterfall model in large-scale development. Lecture Notes in Business Information Processing 32 LNBIP, 386–400. https://doi.org/10.1007/978-3-642-02152-7_29

Prasetyo, S.Y.J., 2023. Software Engineering Course Module.

Pressman, R.S., 2010. SOFTWARE ENGINEERING: A PRACTITIONER'S APPROACH, SEVENTH EDITION, 7th ed. McGraw-Hill. https://doi.org/10.1145/336512.336521

Radhamani, R., Kumar, D., Nizar, N., Achuthan, K., Nair, B., Diwakar, S., 2021. What virtual laboratory usage tells us about laboratory skill education pre- and post-COVID-19 : Focus on usage, behavior, intention and adoption. Educ Inf Technol (Dordr) 26, 7477–7495. https://doi.org/10.1007/s10639-021-10583-3
Ratamun, M.M., Osman, K., 2018. The Effectiveness Comparison of Virtual Laboratory and Physical Laboratory in Nurturing Students' Attitude towards Chemistry. Creat Educ 09, 1411–1425. https://doi.org/10.4236/ce.2018.99105
Ruano, I., Estevez, E., Gamez, J., Gomez, J., 2023. Standards for the Integration of Online Laboratories with Learning Management Systems. IEEE Access.
Sabran, Purnamawati, Nasruddin., 2020. Implementation of IoT-Based Smart Lab Automation in the Digital Laboratory of the Electrical Engineering Education Department, FT-UNM. JETC 15, 1–23.
Saputro, B., 2017. RESEARCH AND DEVELOPMENT MANAGEMENT FOR THESIS AND DISSERTATION PREPARERS. AswajaPressindo, Yogyakarta.
Stark, E., Bistak, P., Kucera, E., 2018. Virtual laboratory with experiment manager implemented into Moodle. Proceedings of the 29th International Conference on Cybernetics and Informatics, K and I 2018 2018-Janua, 1–6. https://doi.org/10.1109/CYBERI.2018.8337541
Valieiev, R.H., 2023. TRENDS OF IMPLEMENTATION OF SCORM PACKAGES IN HIGHER EDUCATION. Publishing House "Baltija Publishing."
Voutama, A., Novalia, E., 2022. Designing a Web-Based Graduation Plaque Information System Using UML and the Waterfall Model. Syntax: Journal of Informatics 11, 36–49.
Widowati, A., Nurohman, S., Setyowarno, D., 2017. Development of Inquiry-Based Science Virtual Laboratory for Improving Student Thinking Skills of Junior High School. Journal of Mathematics and Science Education 5, 170–177. https://doi.org/10.21831/jpms.v5i2.16708