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Development of Practical Photoelectric Effect Based on Arduino Uno: Instrument Validation Analysis

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Abstract

Modern Physics Practicum is a supporting course for Modern Physics (theory). The limitations of the practicum unit are the focus of the problem in this research. This research was conducted to develop a Photoelectric Effect practicum device based on Arduino Uno. This research is a descriptive study that aims to describe the validity of the Arduino Uno-based photoelectric effect practicum device. The research instrument is a validation sheet for practical equipment. The validation results show that the Arduino Uno-based Photoelectric Effect practicum unit developed is in the valid category and suitable for use. However, there are several revisions which are suggestions and constructive comments from validators. The part that requires revision is the aspect of ease and safety in using the tool (Photoelectric Effects practicum unit) and considering designing the toolbox (acrylic) in a dark color. Recommendations for further research could examine the sensitivity of the Arduino Uno-based Photoelectric Effect practical unit at blue wavelengths, to obtain Planck constant measurement results that are more accurate or close to the theoretical value.

Keywords: Arduino uno, modern physics, photoelectric effect

Introduction

Modern Physics is one of the core subjects of the Physics Education Study Program. Apart from being abstract, Modern Physics also studies the behavior of particles that move above the speed of light, studying the behavior of particles that classical physics can no longer study. Modern Physics courses also often present problems that require students to think critically and systematically in solving case examples in the realm of Modern Physics (Rianti et al., 2020). In addition, the content of Modern Physics material connects classical and modern theoretical concepts, such as the concepts of Relativity and Particle-Wave Dualism (Sartika & Humairah, 2018). Students will have difficulty understanding advanced Physics concepts such as Quantum Physics, if they do not previously have a perfect understanding of Modern Physics concepts. Learning Modern Physics is not enough if it only emphasizes Physics content in physics textbooks (Ozdemir, 2017).

One of the contents of Modern Physics which is abstract and is one of the essential contents of Modern Physics is the Photoelectric Effect. The photoelectric effect is the process of electrons jumping in a vacuum tube due to the influence of an increase in voltage. After analyzing these elec-

tron jumps, Planck's constant will be found as a standard form of measuring electricity and mass (Park et al., 2019). Furthermore, the photoelectric effect is also defined as a phenomenon when electrons are released because the photon frequency is greater than the frequency of the metal being hit by light. In the photoelectric effect, light is not only viewed as a wave but also as an energy carrier (Levrini & Fantini, 2013; Yeşildağ Hasançevi & Günel, 2013). Abstract concepts from Modern Physics require practicum in understanding the material. Therefore, several Physics Education Study Programs in Indonesia have added Modern Physics Practicum as one of the mandatory courses.

The results of initial observations in several Physics Education Study Programs at private universities in South Sulawesi showed that Modern Physics practicum units were still very limited, there were even Physics Education Study Programs that did not add Modern Physics Practicum courses to the study program curriculum due to limited funds to provide practicum units. lack of Human Resources (lecturers) who can design Modern Physics practicum units either manually or digitally, and a lack of laboratory space infrastructure that meets the requirements of a modern physics laboratory (Dewi Hikmah Marisda et al., 2023).

The development of information and communication technology has brought many changes to the world of education, learning, assessment, and learning tools (D H Marisda & Ma'ruf, 2021; Padillo et al., 2023). One of the uses of technology in developing learning tools is designing digital physics practicums (Nurlina et al., 2022). At the beginning of technological developments, physics education researchers designed virtual practicums (Maruf & Sultan, 2023) such as the Phet application and other virtual laboratories (Susilawati et al., 2022). In the virtual laboratory, students can change manipulated variables in virtual form via a laptop or smartphone screen, to then see changes in the response variable (Candido et al., 2022). Apart from that, there are also practicums designed to utilize sensors. The use of sensors can convey information in the form of presenting Physics content effectively and efficiently to students (Hamzah et al., 2022). One of the sensors commonly used in learning is the Arduino Uno sensor. The use of Arduino Uno as a tool in designing physics experimental units includes developing experimental tools to determine static and kinetic friction coefficients (Pramudya et al., 2020). Density measurement with Arduino Uno (Matsun et al., 2022), development of a digital distance measuring tool based on Arduino Uno (Megananda et al., 2021), and development of practical tools for measuring air speed using the Arduino Uno microcontroller (Indrasari et al., 2021).

Analysis of initial observations and the need for developing a Modern Physics practicum unit, it is necessary to develop a Modern Physics practicum tool to support the mastery of Physics concepts of Physics teacher candidates and cover the achievements of Modern Physics lectures. Apart from that, having a Modern Physics practicum can prevent students from misunderstanding the abstract material contained in Modern Physics (Swandi et al., 2020). From the results of previous preliminary research, it was agreed to develop a Photoelectric Effects practicum unit. The practicum unit developed is an Arduino Uno-based Photoelectric Effects practicum unit which is equipped with a digital practicum module. In developing a practicum unit, apart from paying attention to the analysis of user needs, you must also pay attention to the feasibility of the product being developed. A product or instrument is said to be effective when it can measure what it is supposed to measure (Dewi Hikmah Marisda et al., 2022) and can measure the specified variables accurately. So, to obtain research instruments or products that are suitable and effective to use, validation measures need to be carried out. Validation is very important before using an instrument or product in further research (Mirza et al., 2021). The validation chosen is device validation by experts. Instru-

ment validity is the suitability of an instrument to measure what it should measure (Wesnawa et al., 2022).

Materials and methods

This research is a descriptive study that aims to describe the validity of the Arduino Uno-based photoelectric effect practicum device and digital practicum module. The research instrument is a validation sheet for practical equipment. The practical device produced as a product in previous development research was the Arduino Uno-Based Photoelectric Effect Practicum Device. The validity used in this research is expert validation. The aspects assessed in the validation of the Arduino Uno-Based Photoelectric Effect practicum device are 1) suitability of the device with the content of Modern Physics material, 2) ability of the tool to increase student competency, 3) ease of use (operation) of the practicum device, 4) convenience equipment maintenance, 5) accuracy of practical measurement results, 6) safe construction for users, 7) aesthetic value. After the expert provides a feasibility assessment, the Arduino Uno-Based Photoelectric Effect practicum device is then revised based on suggestions and input from the validator. The practicum device validation analysis technique used is the Aiken Validation index by takes into account suggestions and comments from validators.

The research subject is a Photoelectric Effect practicum device based on the photoelectric effect, namely a practicum unit. The research tools were validated by 7 (seven) competent experts. The assessment given by the validator consists of 5 (five) criteria as follows:

Table 1. Instrument Item Assessment Criteria by Validator

Value	Description
1	Irrelevant
2	Less relevant
3	Enough
4	Relevant
5	Very relevant

After being assessed by an expert, the researcher then calculated the assessment results using a validity index, including the index proposed by Aiken as follows.

$V = (\sum S)/(N(c-1))$, where $s = r - lo$ ……. (1)

Information:

r = rater rating

lo = low category assessor rating

c = highest category

N = number of assessors/respondents (Aiken, 1980)

Next, the level of validity is determined using the criteria as shown in Table 2 below.

Table 2. Validity Level Criteria

V Index Range	Category
$V \geq 0{,}75$	Valid
$V < 0{,}75$	Invalid

(Azwar, 2012)

Apart from assessing the items assessed from each indicator, at the validation stage data was also obtained in the form of suggestions and comments from the validator, which were then used as a basis for carrying out improvements and refinements to the practical tools being developed. Suggestions submitted by validators will be analyzed so that they become suggestions that support and build on improving the product being developed (Yusoff, 2019).

Results and Discussion

One important stage in developing practical tools is the validation stage. The validation stage of the product being developed is very necessary to test the validity of the Arduino Uno-Based Photoelectric Effect Practicum Device being developed (Hartini et al., 2018; Winarno et al., 2019). Validation was carried out by seven validators for the Arduino Uno-Based Photoelectric Effect Practicum Device that was developed. Apart from assessing the product being developed, the validator also provides constructive suggestions and comments to improve the product being developed so that it is suitable for use. In this article, we will discuss the recapitulation of data analysis obtained from the Arduino Uno-Based Photoelectric Effect Practicum Device validation

Practicum in lecture activities is one of the lecture activities that are familiar to prospective Physics teacher students (Sultan et al., 2023). Practicum supports improving students' ability to understand abstract physics concepts (Darmaji et al., 2019; Sunardi et al., 2022). Likewise, the Arduino Uno-Based Photoelectric Effect Practicum Device practicum in the Modern Physics Practicum. Previously there had been several studies related to modern physics. One of them is research that examines black holes by creating standard astronomical images from synchrotron emissions from relativistic plasma (Goddi et al., 2017). Meanwhile, other research uses virtual practicums with various virtual lab applications, such as the use of virtual PhET in Modern Physics practicums, and virtual laboratories to improve conceptual understanding (Gunawan et al., 2018), the use of technology-based active learning simulations (TEALSim) on modern physics concepts, simulating the theory of relativity with a smartphone (Sumardani et al., 2020). The Modern Physics Practicum which specifically examines the Photoelectric Effect is the use of LEDs as a light source in the Photoelectric Effect Practicum (Garver, 2006). This practicum uses phototubes and LEDs as light sources, not using mercury lamps. From this practicum, we obtained a Planck constant value of more than 10% using several LEDs in the spectrum from 470 nm to 631 nm. By changing the intensity of the LED it is possible to measure electron energy and photocurrent as a function of light intensity.

The content validity of the instrument in this study was determined using expert agreement (Istianti et al., 2022). Researchers use expert validity because the instrument (product) has been proven to be accurate if the expert believes that the instrument can be used to measure research variables (Rahmawati et al., 2018). The validity formula used is Aiken validation. Seven experts assessed the instrument. The results of the content validity analysis of the seven assessors using the Aiken formula can be seen in Table 3 below.

Table 3. Results of Aiken Index Analysis of the Arduino Uno-based Photoelectric Effect Practicum Device Instrument

Indicator	V value	Vtable value	conclusion
Compatibility of the device with the content of Modern Physics material	0,82	0,75	Valid
The ability of tools to improve student compe-	0,75	0,75	Valid

Indicator	V value	Vtable value	conclusion
tence			
Easy of use (operation) of practical equipment	0,89	0,75	Valid
Ease of tool maintenance	0,71	0,75	Invalid
Accuracy of practical measurement results	0,75	0,75	Valid
Construction safety of use for users	0,79	0,75	Valid
Has aesthetic value	0,71	0,75	Invalid

Table 3. Results of the Aiken Index Analysis of the Arduino Uno-based photoelectric effect practicum device Instrument show the validity value of the Arduino Uno-based photoelectric effect practicum device instrument for each indicator. Of the seven Arduino Uno-based photoelectric effect practicum device instrument validation indicators, two indicators have not shown valid values based on the Aiken validation index. These two indicators are the ease of equipment maintenance and the aesthetic value of the practicum unit. The ease of maintenance of the practical instruments developed will greatly support the long service life of the tools developed. Meanwhile, the aesthetic value will attract users (students and lecturers) when carrying out practicums. This is in line with DIVTCELL APP development research which also pays great attention to the aesthetic value of the application being developed. Paying attention to the aesthetic value of the product will have a positive impact on user perception (Mantilla et al., 2023).

Apart from quantitative data analysis from validator (expert) scoring, the validator also provided several comments and suggestions (Mulhayatiah et al., 2022) for improvement of the Arduino Uno-based photoelectric effect practicum device. The validator's comments and suggestions are presented in Table 4 below.

Table 4. The validator's comments and suggestions

Instrument Type	Suggestions and Comments
Photoelectric effect practical unit	. Researchers should pay attention to student safety when using tools. . It is recommended to label the potentiometer knob so that students do not get confused in determining the color during practicum. . The acrylic box covering the practical equipment should be replaced and made darker, consider using black on the tool box.

Table 4. Validator Suggestions and Comments show validator comments when validating the Arduino Uno-based photoelectric effect practicum device instrument. These comments cover aspects of tool use, tool safety, and the aesthetics of practical equipment. Based on the validator's input and suggestions, the lecturer team developing the Photoelectric Effect practicum device made improvements and added several parts to the Photoelectric Effect practicum device and the practicum module that was developed. Comments provided by validators are good suggestions and an important part that must be considered in the suitability of research instruments and products (Elangovan & Sundaravel, 2021). The validator's corrections and comments at the validation stage build the va-

lidity of the instrument being developed (Yulastri et al., 2017). Improving the instrument at the validation stage is the final stage before the research product is tested and implemented either on a limited or widespread basis.

The Arduino Uno-based Photoelectric Effect practical device is designed using a user-friendly microcontroller that is easy to use. Another advantage of the Photoelectric Effect practicum device based on the photoelectric effect is that it can facilitate students in carrying out the Photoelectric Effect practicum, so that from the practicum results students can find voltage variables which will then be analyzed simply in Microsoft Excel to find the Planck constant. At the beginning of the Photoelectric Effect practicum device based on the photoelectric effect design, researchers were constrained by the tool coding process. The coding process is quite sensitive and not flexible to the slightest change. So if there are changes, coding must be done again from the beginning. This is the weakness of this Photoelectric Effect practicum device based on the photoelectric effect research. Apart from that, the Photoelectric Effect practicum device based on the photoelectric effect being developed is quite difficult to obtain measured voltage values at the blue wavelength. Therefore, researchers recommend further research that examines the sensitivity of the Photoelectric Effect practicum device based on the photoelectric effect at blue wavelengths. Apart from that, researchers also recommend the need for advanced coding that connects the Photoelectric Effect practicum device based on the photoelectric effect box to a computer or smartphone, so that students do not need to read it on the screen of the photoelectric effect practical unit device. This can also minimize students' reading errors when doing practicum.

Conclusion

From the results of descriptive research related to the validity of the product being developed, it can be concluded that the content validity of the instrument was obtained through expert agreement with the calculation of the Aiken index; The validity of the instrument content based on the Aiken table is said to be valid if the validity of the instrument is > 0.75. The validity of the content of the Arduino Uno-based photoelectric effect practicum device instrument is declared valid on the indicators of suitability of the device with the content of Modern Physics material, ability of the tool to improve student competency, ease of use (operation) of the practicum device, accuracy of practicum measurement results, and construction safety of use for users. Apart from that, during validation, some expert suggestions and comments require minor revisions to perfect the resulting instrument.

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References

Aiken, L. R. (1980). Content validity and reliability of single items or questionnaires. *Educational and Psychological Measurement*, *40*(4), 955–959. https://doi.org/10.1177/001316448004000419

Azwar, S. (2012). *Reliabilitas dan Validitas* (Edisi IV). Pustaka Pelajar.

Candido, K. J. O., Gillesania, K. C. C., Mercado, J. C., & Reales, J. M. B. (2022). Interactive Simulation on Modern Physics: A Systematic Review. *International Journal of Multidisciplinary: Applied Business and Education Research*, *3*(8), 1452–1462. https://doi.org/10.11594/ijmaber.03.08.08

Darmaji, D., Kurniawan, D. A., & Irdianti, I. (2019). Physics education students' science process skills. *International Journal of Evaluation and Research in Education*, *8*(2), 293–298. https://doi.org/10.11591/ijere.v8i2.28646

Elangovan, N., & Sundaravel, E. (2021). Method of preparing a document for survey instrument validation by experts. *MethodsX*, *8*. https://doi.org/10.1016/j.mex.2021.101326

Garver, W. P. (2006). The Photoelectric Effect Using LEDs as Light Sources. *The Physics Teacher*, *44*(5), 272–275. https://doi.org/10.1119/1.2195395

Goddi, C., Falcke, H., Kramer, M., Rezzolla, L., Brinkerink, C., Bronzwaer, T., Davelaar, J. R. J., Deane, R., De Laurentis, M., Desvignes, G., Eatough, R. P., Eisenhauer, F., Fraga-Encinas, R., Fromm, C. M., Gillessen, S., Grenzebach, A., Issaoun, S., Janßen, M., Konoplya, R., … Zhidenko, A. (2017). BlackHoleCam: Fundamental physics of the galactic center. *International Journal of Modern Physics D*, *26*(2), 1–37. https://doi.org/10.1142/S0218271817300014

Gunawan, G., Nisrina, N., Suranti, N. M. Y., Herayanti, L., & Rahmatiah, R. (2018). Virtual Laboratory to Improve Students' Conceptual Understanding in Physics Learning. *Journal of Physics: Conference Series*, *1108*(1). https://doi.org/10.1088/1742-6596/1108/1/012049

Hamzah, H., Sartika, D., & Agriawan, M. N. (2022). Development of Photoelectric Effect Learning Media based on Arduino Uno. *Indones. Rev. Phys*, *5*(1), 8–15. https://doi.org/10.12928/irip.v5i1.5830

Hartini, S., Firdausi, S., Misbah, & Sulaeman, N. F. (2018). The development of physics teaching materials based on local wisdom to train Saraba Kawa characters. *Jurnal Pendidikan IPA Indonesia*, *7*(2), 130–137. https://doi.org/10.15294/jpii.v7i2.14249

Indrasari, W., Rustana, C. E., & Zulfikar. (2021). Development a practicum tools to measure the speed of the air using Arduino Uno Microcontroller. *Journal of Physics: Conference Series*, *1816*(1). https://doi.org/10.1088/1742-6596/1816/1/012109

Istianti, T., Maryani, E., & Maftuh, B. (2022). Validity of Conflict Resolution Education Model based on Sabilulungan Local Wisdom to Build Conflict Resolution Competency of Elementary School Students. *European Online Journal of Natural and Social Sciences*, *11*(4), 1037–1049. http://www.european-science.com

Levrini, O., & Fantini, P. (2013). Encountering Productive Forms of Complexity in Learning Modern Physics. *Science and Education*, *22*(8), 1895–1910. https://doi.org/10.1007/s11191-013-9587-4

Mantilla, S. A. A., Macababat, L. A., Nasayao, R. D. S., & Walag, A. M. P. (2023). Design, Development, And Evaluation Of Divtcell App: Gamifying Eukaryotic Cell Division And Its Effects On Academic Achievement. *Jurnal Pendidikan IPA Indonesia*, *12*(2), 199–207. https://doi.org/10.15294/jpii.v12i2.43852

Marisda, D H, & Ma'ruf, M. (2021). Situation analysis of mathematical physics learning with online learning during the COVID-19 pandemic Situation analysis of mathematical physics learning with online learning during the COVID-19 pandemic. *Journal of Physics: Conference Series*, 1–6. https://doi.org/10.1088/1742-6596/1806/1/012034

Marisda, Dewi Hikmah, Rahmawati, ., Riskawati, ., Basri, S., & Anisa, . (2022). Analyzing the Validity of Interactive Multimedia-based Learning on Acid Rain Content. *KnE Social Sciences*, *2022*. https://doi.org/10.18502/kss.v7i12.11534

Marisda, Dewi Hikmah, Sultan, A. D., Basri, S., & Sakti, I. (2023). *Digital-Based Photoelectric Effect Curriculum and Student Analysis Practicum Toolkit : 9*(11), 9410–9415. https://doi.org/10.29303/jppipa.v9i11.5014

Maruf, M., & Sultan, A. D. (2023). Analysis of The Use of Interactive Multimedia Android Thermodynamics to Reduce Student Misconceptions. *European Online Journal of …*, *12*(1), 213–219. https://european-science.com/eojnss/article/view/6660%0Ahttps://european-science.com/eojnss/article/download/6660/3105

Matsun, M., Boisandi, B., Sari, I. N., Hadiati, S., & Zadrianus, M. T. (2022). Development of Arduino Uno-based real learning media for measuring density of objects. *Jurnal Riset Dan Kajian Pendidikan Fisika*, *9*(1), 25–33. https://doi.org/10.12928/jrkpf.v9i1.27

Megananda, A., Muzayyanah, E., Darmayanti, H. P., & Priana, Z. I. (2021). Development of Digital Distance Measurement Instrument Based on Arduino Uno For Physics Practicum. *Journal of Research and Innovation in Physics Education*, *1*(2), 80–88. http://ejournal.uin-suka.ac.id/tarbiyah/impulse

Mirza, M. A., Khurshid, K., Sohail, K., Biland, S., & Mirza, A. A. (2021). Validation of ils through exploratory factor analysis and internal consistency reliability for secondary grade. *International Journal of Information and Education Technology*, *11*(4), 189–193. https://doi.org/10.18178/ijiet.2021.11.4.1510

Mulhayatiah, D., Sinaga, P., Rusdiana, D., Kaniawati, I., & Junissetiawati, D. (2022). Modern Physics E-book Based Multirepresentation for Hybrid Learning. *European Online Journal of Natural and Social Sciences*, *11*(4), 1166–1177. http://www.european-science.com

Nurlina, Marisda, D. H., Riskawati, Sultan, A. D., Sukmawati, & Akram. (2022). Assessment On Digitalization Of Basic Physics Courses: Need Analysis On The Use Of Digital-Based Assessment. *Jurnal Pendidikan IPA Indonesia*, *11*(4), 531–541. https://doi.org/10.15294/jpii.v11i4.39191

Ozdemir, E. (2017). Comics in Modern Physics: Learning Blackbody Radiation through Quasi-History of Physics. *Studies in Educational Research and Development Volume*, *1*(1), 41–59. http://ezproxy.lib.uconn.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED579152&site=ehost-live

Padillo, G. G., Nacorda, R. F. T., Conag, J. M. N., Ramil, P., Espina, R. C., Capuno, R. G., & Etcuban, J. O. (2023). *Learning Styles and Technology Implementation of Special Education Teachers in the New Normal*. *12*(2), 241–261.

Park, W., Yang, S., & Song, J. (2019). When Modern Physics Meets Nature of Science: The Representation of Nature of Science in General Relativity in New Korean Physics Textbooks. *Science and Education*, *28*(9–10), 1055–1083. https://doi.org/10.1007/s11191-019-00075-9

Pramudya, C. T., Islami, N., Azizahwati, & Rahmad, M. (2020). Development of Static and Kinetic Friction Coefficient Experiment Device Based on Arduino Uno. *Journal of Physics: Conference Series*, *1655*(1). https://doi.org/10.1088/1742-6596/1655/1/012049

Rahmawati, Rustaman, N. Y., Hamidah, I., & Rusdiana, D. (2018). The development and validation of conceptual knowledge test to evaluate conceptual knowledge of physics prospective teachers on electricity and magnetism topic. *Jurnal Pendidikan IPA Indonesia*, *7*(4), 483–

490. https://doi.org/10.15294/jpii.v7i4.13490

Rianti, S., Akhsan, H., & Ismet, I. (2020). Development Modern Physics Digital Handout Based on Technology Literacy. *Berkala Ilmiah Pendidikan Fisika*, *8*(1), 23–32. https://doi.org/10.20527/bipf.v8i1.7593

Sartika, D., & Humairah, N. A. (2018). Analyzing Students' Problem Solving Difficulties on Modern Physics. *Journal of Physics: Conference Series*, *1028*(1). https://doi.org/10.1088/1742-6596/1028/1/012205

Sultan, A. D., Kurniawan, R., & Nurfadillah, N. (2023). *Design and Analysis of the Basic Physics Practicum Model Based on the Higher Order Thinking Laboratory as a Model for 21st Century Learning Practicum*. *12*(2), 233–240.

Sumardani, D., Putri, A., Saraswati, R. R., Muliyati, D., & Bakri, F. (2020). Virtual Reality Media: The Simulation of Relativity Theory on Smartphone. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *10*(1), 13–24. https://doi.org/10.30998/formatif.v10i1.5063

Sunardi, S., Suhandi, A., Darmawan, D., & Muslim, M. (2022). Investigation of Student Difficulties in Physics Learning and Readiness to Implement Physics Learning Using Bifocal Modeling-Based Practicum in Indonesia. *European Online Journal of Natural and Social Sciences*, *11*(4), 1091–1102. http://www.european-science.com

Susilawati, S., Doyan, A., Mulyadi, L., Abo, C. P., & Pineda, C. I. S. (2022). The Effectiveness of Modern Physics Learning Tools Using the PhET Virtual Media Assisted Inquiry Model in Improving Cognitive Learning Outcomes, Science Process Skills, and Scientific Creativity of Prospective Teacher Students. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 291–295. https://doi.org/10.29303/jppipa.v8i1.1304

Swandi, A., Amin, B. D., Viridi, S., & Eljabbar, F. D. (2020). Harnessing technology-enabled active learning simulations (TEALSim) on modern physics concept. *Journal of Physics: Conference Series*, *1521*(2). https://doi.org/10.1088/1742-6596/1521/2/022004

Wesnawa, I. G. A., Kartowagiran, B., Jaedun, A., Hamdi, S., Hadi, S., Susantini, E., Sunendar, D., Laliyo, L. A. R., Christiawan, P. I., & Divayana, D. G. H. (2022). Content Validation of Digital Instrument for Measurement of Pedagogic Competence for Social Science Teacher Candidates in the Industrial Revolution 4.0 Era in Indonesia. *International Journal of Information and Education Technology*, *12*(12), 1424–1430. https://doi.org/10.18178/ijiet.2022.12.12.1767

Winarno, W., Muhtadi, Y., & Aldiya, M. A. (2019). Application of Learning Management Using Non-test Instrument to Improve the Quality of Education. *Aptisi Transactions on Management (ATM)*, *3*(1), 46–56. https://doi.org/10.33050/atm.v3i1.831

Yeşildağ Hasançevi, F., & Günel, M. (2013). College Students' Perceptions toward the Multi Modal Representations and Instruction of Representations in Learning Modern Physics. *Eurasian Journal of Educational Research*, *53*, 197–214. https://doi.org/10.14689/ejer.2013.53.11

Yulastri, A., Hidayat, H., Ganefri, Islami, S., & Edya, F. (2017). Developing an Entrepreneurship Module by Using Product-Based Learning Approach in Vocational Education. *International Journal of Environmental and Science Education*, *12*(5), 1097–1109.

Yusoff, M. S. B. (2019). ABC of Content Validation and Content Validity Index Calculation. *Education in Medicine Journal*, *11*(2), 49–54. https://doi.org/10.21315/eimj2019.11.2.6