Developing User-Friendly E-module Hyper-content on Atomic Structure and Periodical Properties of Elements

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Abstract. Connecting understanding on atomic structure to explain the periodical properties of elements has always been a challenge over the years. One of the factors behind this is the lack of availability of syllabus-relevant, user-friendly, practical and accessible learning resources on the topics. Therefore, this research and development study aims to produce a valid and practical e-module hyper-content to support the learning process of structure atom and periodical properties of element by preservice science teachers. The e-module was developed through ADDIE model which consists of five stages namely Analysis, Design, Develop, Implementation, and Evaluation. The validity test of the product was conducted through expert judgements and the practicality test was conducted involving 110 third semester students of Science Education Department of Universitas Negeri Padang. Result of the feasibility test indicated that the e-module with hyper-content on structure atom and periodical properties of elements belongs to very high category for both validity and practicality. Analysis of students’ responses on open-ended questionnaires revealed that this e-module is beneficial for better learning on the topic due to the ease of use and integrative way of presenting information on relevant topics.

1. Introduction
The advance development of knowledge and technology in 4.0 Industrial Revolution has eventually forced learning process in higher education to adapt at all costs. Students have to embrace the new phenomena of “big data”, “internet of things” as well as “internet of people” in their everyday life [1]. Nowadays, students are forced to adapt with new ways of learning, which contain minimum classroom typical face-to-face interaction to the more technology-and-internet-based learning style. E-learning platforms, digital classrooms, and digital teaching materials have become common items in every student’s daily activities The use of smartphones in classroom, which has been initiated since a few years ago to help students find information easier and faster [2], now has become more intense approaching to become a regular daily basis The easiness to access various forms of learning resources has enable students to explore their creativity in finding information [3]. The ever-lasting pandemic of Covid-19 plays a great role to this new normal, since it has shown no sign of going to die down in this near future. However, this ease of access has come with its own typical problems, which related to the supporting infrastructure and particular skills for managing information [2,4] and judging the validity and reliability of any information they came across with in order to be used appropriately [1].

Atomic structure and periodical properties of elements are two chapters in Basic Inorganic Chemistry course that is mandatory in second and third semester to all students in science education
department of Universitas Negeri Padang. These two topics are particularly essentials to all preservice science teachers since they help build better understanding to related secondary school science topics, such as atom, ion, and molecule. Good understanding on these two topics will surely provide good support to preservice science teachers’ professional competency and self-confidence. In addition, sound understanding on these topics will also help students to build better scientific explanation to relevant phenomena \cite{5,6,7}\ as stated as the goal of science education in school. However, teaching experiences revealed that since 2016 until 2019, most students were still difficult to achieve all expected learning outcomes. One example of this difficulty is students’ inability to write down correct electron configuration for ions (both cation and anion) even though they have managed to write that of the ground state configuration correctly\cite{8}.

In Indonesian context, university students are not new to these two topics for they have studied them twice, in senior secondary school and in the first year in university. The presentations of these two topics in those two levels of education were not that much different. Therefore, since 2016 we tried to map out students difficulty in learning these topics as presented in Figure 1 below.

![Figure 1. Problem Identification for Basic Inorganic Course in Science Education Department of Universitas Negeri Padang](image)

Regarding the first problem, even if there are some handouts or teaching material written by some lecturers in famous universities in Indonesia, the content of such materials are not always suitable to be used in our department. This is understandable because each university of course design teaching materials to address particular competencies or skills for the students to develop. However, this first problem is possible to decrease the effectiveness of classroom learning interaction to construct new knowledge because students rely too much on handouts from lectures. In normal classroom learning, the handout usually distributed after one topic is discussed, which means during the presentation from lecturer, students most likely to sit, listen, and maybe taking some notes. If this habit continues,
students’ independence in finding learning resources will lead to lack of creativity which is necessary for science teachers.

The second problem is quite urgent to be solved because it is related to the quality of preservice teachers from Universitas Negeri Padang. Inability to explain observed phenomena or experimental data is a major setback for students. The third problem is also urgent to be addressed because this also indicates students’ inability to cope up with the advance in technology and information. The ease to access information should be accompanied by the skills to justify the validity and reliability of information or sources before taking it in. Lack of this justification skill could also potentially reduce students’ independence in learning.

The fourth problem is quite common found in science classroom, especially in school level. The excitement to be appointed by teachers to answer particular type of questions sometimes stimulate students to work hard finding the answer rather than spending some times to read carefully what was the information about. The fifth problem is related to English communication skills. Most students were seemed reluctant to be given some free e-books from the internet. In this Disruptive Era, in which information could easily travel from one continent to others, language barrier should be overcome by the students themselves. However, since learning foreign language takes a lot of time, the other four problems came first to be solved.

Content-wise, atomic structure and periodical properties of elements are quite challenging to master. Atomic structure is considered as moderately difficult topics among students in a university in Indonesia [9]. The abstract nature of the concepts and complexity of interrelated factual information required to sufficiently understand the topic have been known to become obstacle to students’ learning [10]. Not to mention students’ tendency to develop misconception prior, during, or even after learning process [11,13,14,15]. Regarding the topic atomic of structure, our teaching experience revealed that there are several learning tasks that students were still struggling to deal with. For example, explaining the chronological development of atomic model from one model to the next, explaining anomaly behind some electron configurations, and writing electron configurations for ions (Sari, Hardinata, Andromeda, & Bayharti, 2019). This finding actually confirms with other study which also reported that college students tend to use simple heuristics to deal with this kind of chemistry problems without further consideration of chemical context [16].

In previous study, we found several perceived difficulties in learning periodical properties of elements. Almost half of the students (46.5 %) stated that they were having difficulty to grasp the concepts in periodical properties of elements, too many information to be memorized, too complicated, difficult to understand (Sari, Andromeda, & Hardinata, 2020). Some students admitted that they were having difficulty in memorizing so many chemical elements from periodic table, along with their atomic numbers, period, and group whether they are main group of transition group elements. Other perceived difficulties are the pace of classroom learning, insufficient understanding from previous learning (in high school), and lack of accessible relevant learning resources [17]. We also found that some of these difficulties could combine together as experienced by some individuals. For example, few students stated that they couldn’t keep up with the learning pace in classroom, probably related to insufficient understanding from senior high school chemistry and they could not find any relevant learning resources in Bahasa (the main instructional language of teaching). Some of these findings confirm with several factors behind junior secondary school students’ misconceptions on the topic of matter and it’s properties [18,19]. Since science student teachers will become secondary science teachers, it’s important to build sound understanding on this topic in order to avoid the same misconceptions in the future [20,21].

E-module is a solution that we proposed to overcome one of students learning difficulty for periodic properties of elements, which is also expected to indirectly solve other difficulties. As we found on another study, students of science education department of Universitas Negeri Padang wish to have a learning resource that: 1) use Bahasa, 2) contain picture and colors, 3) complete materials and worked examples, and 4) stimulate students’ thinking [22]. These characteristics could be found all in one electronic module. E-module enables students to study individually to match their learning style.
and pace in processing all the information required to master the expected learning outcomes. In addition, e-module also provide a new challenge for students in processing new information with technology which is totally different compared to the traditional way of teaching [1], which hopefully motivate them to study further.

With e-module, students’ are free to decide when and where they want to study [4,23,24] either with or without using internet connection. This choice apply pretty well for Indonesian context, at which students in rural areas are most likely to experience difficulty accessing internet connection, e-module could still provide instruction materials to support their learning. The effectiveness of e-module to support e-learning has been claimed in several studies, especially for Physics [25] and Chemistry courses [26]. The hyper content feature of this e-module is expected to provide students with various relevant resources in the forms of websites, evaluation forms, and experiment or animation videos to help students better understand the concepts presented. This way of presentation is made possible thanks to advance of e-module applications or makers which enable e-learning to be customized to match students’ personal style [24].

The use of e-module in chemistry subjects or courses has been proven to be effective and practical in several studies. For example, e-module is effective to improve students’ chemical literacy skills [27], and practical to support green chemistry as learning media for alternative fuel topics [28] and acid-base titration [26]. We believe that by providing an accessible and customized learning resource, students could strengthen their confidence and independence learning to build their own knowledge and stimulate their thinking skills (Muttaqiin, Putri, Sari, 2019), particularly in formulating scientific explanation. E-module could also help students to cope with the never-resting technological development in this 4.0 industrial revolution, where that they could use technology to study and find information and build knowledge anywhere at anytime. In addition, the use of e-module in teaching could be an example of paper-less lifestyle and support the campaign of “save our forest” which is already a part of commitment for everyone wishing to become a science teacher.

2. Methods
This Research and Development research adopted ADDIE in developing e-module hyper-content on the topic of atomic structure and periodical properties of elements. ADDIE model consist of five stages namely: Analysis, Design, Develop, Implementation and Evaluation. This model is already common to be used in developing teaching materials, either in form of learning material, module and e-module, or students’ worksheet. Each stage has particular activities which can be seen in Figure 2 below for further detail.

ADDIE model has been widely used and modified in designing instruction materials for various subjects and courses. To name a few, ADDIE model has been used to design an electronic module for electric circuits [30] and for heat and temperature [31] in Physics, as well as to design a module for senior high school Mathematics subject with Kvisoft Flipbook Maker [32] and actuarial mathematics [33], for colligative properties of matter [27] and alternative fuels materials for Chemistry subjects [28], and for History course [34]. Even though some studies reported limitation of ADDIE model, this model is still the most common model used to develop instruction materials.
3. Result and Discussion

E-module in this study presents the material of structure atom and periodical properties of elements by adapting the structure in which they are presented in international standard textbooks with some modification to make it suitable for science student teachers. By doing so, we intended to simplify the presentation of some topics and emphasize more on the process skills, particularly thinking skills which enable them to link one concept to others in order to create a good scientific explanation and argumentation. During the analysis stage, which the complete result has been described elsewhere \cite{22}, we conducted a series of focus group discussions to come up with the expected learning outcomes for science student teachers as can be seen in Table 1 below.

As mentioned in introduction section, proposing scientific explanation is still difficult among students in science education department of Universitas Negeri Padang. Since this is an essential skill required as a future science teacher, an intervention in learning process needs to be conducted. On Table above, expected learning outcomes in italic form are those came during the Focus Group Discussion (FGD) which was considered to be appropriate to stimulate such skills. Consequently, during the Design stage, we also decided to give more problems containing data and cases to stimulate students’ thinking. We also decided to add some features such as link to eternal sources, news article, and videos to help students connect their understanding to other relevant chemistry concepts. Since
this e-module was also intended to be used in online learning system, at the end of each chapter there is a link to an online testing form for students to check their understanding.

**Table 1.** Indicators of The Expected Learning Outcomes of Atomic Structure and Periodical Properties of Elements [22].

| Indicator for the Learning outcomes for atomic structure | Indicator for the Learning outcomes for periodical properties of elements |
|---------------------------------------------------------|---------------------------------------------------------------------------|
| 1. To explain the development of atomic models (from Dalton to Bohr) chronologically. | 1. To explain the periodical properties of atomic radii (covalent radius) and ionic radius of elements in periodic table. |
| 2. To explain the setbacks of each atomic model. | 2. To explain the concept of shielding effect and its relation to atomic and ionic radius. |
| 3. To explain the setbacks of Bohr’s atomic model that triggers the development of quantum mechanic theory. | 3. To calculate the effective nuclear charges ($Z^*$) and explain its relation to periodical properties of atomic and ionic radius. |
| 4. To explain how to determine four quantum numbers to locate the orbital of electrons. | 4. To explain the concept of ionization energy and its periodical properties. |
| 5. To write down electron configuration based on the Aufbau principle, Hund’s rule, and Pauli’s principle of exclusion. | 5. To explain the relationship between periodical properties of ionization energy of alkaline and earth alkaline group to their respective effective nuclear charges. |
| 6. To explain the anomaly of electron configuration of particular elements on the periodic table | 6. To explain the concept of electron affinity and its periodical properties. |
| 7. To explain the concept of electronegativity and it’s periodical properties. | |

Note: learning outcomes in italic are those meant to stimulate students’ ability to propose a scientific explanation

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**Figure 3.** Cover of e-module on atomic structure and periodical properties of elements

The image on the cover of e-module was taken from https://dreamstime.com which was considered the most representatives to the content of e-module. Meanwhile, the arrangement of content was the
result from researchers’ team based on the analysis of content from international standard textbook for inorganic chemistry.

| DAFTAR ISI |
|------------|
| Halaman |
| I. STRUKTUR ATOM | 1 |
| A. Sejarah Perkembangan Model Atom | 2 |
| B. Model Atom Melembut Gelombang | 3 |
| C. Orbital dalam Model Atom Melembut Gelombang | 6 |
| D. Betangan Kerumun | 9 |
| E. Kajian Elektron | 11 |
| 1. Prinsip Aufbau dan Shelidng Effect | 12 |
| 2. Aturan Hund dan Multipliter | 15 |
| F. Asal Larangan Pauli dan Sifat Kompilasi Unsur | 19 |
| G. Peranan Posit Unsur dalam Tabel Periodik | 21 |
| H. KUMPILUNTUS 1 | 23 |
| I. SIFAT PERIODIK UNSUR | 24 |
| A. Shelidng Effect dan Multai Ini Effesit | 25 |
| B. Jari Peri Atom dan Ion | 27 |
| C. Energi total | 33 |
| D. Atomal Elektron | 36 |
| E. Kekaretarafan | 39 |
| F. KUMPILUNTUS 2 | 42 |
| DAFTAR REFERENSI | 45 |

**Figure 4.** Table of content in the e-module hyper content on atomic structure and periodical properties of elements

**Figure 5.** Sample page from e-module hyper content on atomic structure and periodical properties of elements
From the sample page in Figure 5 above, it can be seen that link to the relevant experiments and animations for was atomic model were provided, so that students could just click the link or scan the QR code then they will be presented with the content instantly. However, the speed of content to appear still depends on the availability of internet connection and its quality. During the limited trial, most students did not experience long delay to see the content for each links.

### Table 2. Result of Feasibility Test on Content Aspect

| No. | Indicators of Content Aspects | Agreement (average score in %) |
|-----|-------------------------------|-----------------------------|
| 1.  | Material Coverage (2 sub indicators, i.e. the suitability of material presented in the module with the expected learning outcomes) | 100% |
| 2.  | Material Accuracy (4 sub indicators, i.e. the accuracy of factual information presented in the module and it’s effectiveness to facilitate students’ understanding) | 100% |
| 3.  | Sophistication (3 sub indicators, i.e. the materials are up-to-date in terms of knowledge development and relevant to nowadays-world) | 87.5% |
| 4.  | Contains Productivity Insight (4 sub indicators, i.e. foster the spirit of hard work, motivational sample problems, challenging exercise) | 87.5% |
| 5.  | Stimulates curiosity (3 sub indicators, i.e. provide triggers stimulate students to think further and explore more information) | 100% |
| 6.  | Develop life skills (3 sub indicators, i.e. providing context or problems to allow students to check their strength and weaknesses in terms of learning) | 83.3% |
| 7.  | Contains Contextual Insight (2 sub indicators, i.e. providing real life examples from local environment, as well as from national and international) | 75% |

**Average** 90.47%

### Table 3. Result of Feasibility Test on Language Aspect

| No. | Indicators of Content Aspects | Agreement (average score in %) |
|-----|-------------------------------|-----------------------------|
| 1.  | Suitability with students’ level of development (2 sub indicators, i.e. the suitability with students’ socio-emotional development) | 100% |
| 2.  | Communicative (2 sub indicators, i.e. interesting word choices, appropriate use of illustration) | 100% |
| 3.  | Dialogic and interactive (i.e. stimulate enjoyment in studying the material through e-module) | 100% |
| 4.  | Straightforwardness (2 sub indicators, i.e. the use of standardized terms; appropriateness of structures of sentences) | 87.5% |
| 5.  | Coherence and Systematic (2 sub indicators, i.e. coherence in meaning for each chapter/paragraph) | 100% |
| 6.  | Suitability with language rules | 100% |
| No. | Indicators of Content Aspects                                                                 | Agreement (average score in %) |
|-----|-----------------------------------------------------------------------------------------------|-------------------------------|
| 7.  | The use of terms and symbols (2 sub indicators, i.e. the consistency in using terms, symbols, and unit). | 87.5%                         |

**Average** 96.42%

**Table 4. Result of Feasibility Test on Presentation Aspect**

| No. | Indicators of Content Aspects                                                                 | Agreement (average score in %) |
|-----|-----------------------------------------------------------------------------------------------|-------------------------------|
| 1.  | Suitability with students’ level of development (4 sub indicators, i.e. consistency of presenting material systematically; the logic of presentation) | 100%                          |
| 2.  | The support of material presentation (5 sub indicators, i.e. appropriateness use of picture, illustration, table, and picture). | 87.5%                         |
| 3.  | Overall presentation (3 sub indicators, i.e. providing feedback for self evaluation, stimulate deep thinking). | 81.25%                        |

**Average** 89.58%

**Table 5. Result of Feasibility Test on Graphic Aspect**

| No. | Indicators of Content Aspects                                                                 | Agreement (average score in %) |
|-----|-----------------------------------------------------------------------------------------------|-------------------------------|
| 1.  | Consistency of lay out (3 sub indicators, i.e. the position of chapters’ name, pattern consistency) | 100%                          |
| 2.  | Harmony between elements of lay out (3 sub indicators, i.e. space between text, margins).     | 80%                           |
| 3.  | Lay out helps facilitate understanding better (i.e. elements of lay out do not interfere students’ understanding). | 100%                          |
| 4.  | Simple typography and legibility (6 sub indicators, i.e. font variation and size)            | 100%                          |
| 5.  | Typography helps to understand better (2 sub indicators, i.e. hierarchy of subtitles)       | 80%                           |
| 6.  | Illustrations (3 sub indicators, i.e. proportionality, appealing, meaningful)                | 100%                          |

**Average** 93.33%

From Table 2, 3, 4, 5 respectively, it can be seen that in every aspect this e-module gained high feasibility scores. Based on Figure 6 below, the overall average score of feasibility test from three field experts and two media experts is 92.45% which means this electronic module is valid and highly feasible to be used in Basic Inorganic course for science student teacher. This result is in accordance with feasibility test result with 20 students through limited trial (Table 6). This limited trial gave out feasibility test score of 88.5% which also means highly feasible to be used as leaning resources. Some students even left comments which emphasize on the usefulness of this electronic module by saying: “I wish I had this e-module when I was taking the course”, or “this e-module is really helpful because it’s in Bahasa” or “this e-module is very easy to use, we can save time instead of searching random
resources on the internet anymore”, and so forth. Generally, these students gave positive feedbacks toward this electronic module on atomic structure and periodical properties of elements.

Figure 6. Overall Result of Feasibility Test from Media and Field Experts

Table 6. Result of Feasibility Test with Science Students Teachers through Limited Trial

| No. | Aspects of Feasibility Test | Agreement (average score in %) |
|-----|-----------------------------|--------------------------------|
| 1.  | Content aspects             | 100%                           |
|     | (7 sub indicators, i.e. suitability with learning outcomes, systematic of presentation, ease of use, availability of worked examples) |
| 2.  | Language of presentation    | 83%                            |
|     | (6 sub indicators, i.e. legibility, clarity, consistency of terms and symbols, simplicity of sentences). |
| 3.  | Usefulness                  | 90%                            |
|     | (8 sub indicators, i.e. help facilitate learning and better understanding, trigger curiosity, provides challenges). |
| 4.  | Graphic                     | 81%                            |
|     | (8 sub indicators, i.e. illustration, layout, overall design, clarity of picture and tables) |
|     | **Average**                 | **88.5%**                      |

There were some suggestions came from students related to graphic aspect of this electronic module, such as related to colours, font type and sizes, and also picture sizes. However, during finalization stage of this study, not all suggestions could be executed. As much as we were grateful to accept such suggestions, we would like to maintain the simple and elegant design as proposed by the team.

4. Conclusion

E-module hyper-content was developed through three stages of the ADDIE model, namely Analysis, Design, and Develop until we figured out the feasibility of this electronic module. The stages of Implementation and Evaluation couldn’t be done due to change in curriculum thus the course was not available during this study. Feasibility test with three experts (2 media expert and 3 field expert) revealed that this e-module was valid and highly feasible to be used with the total average agreement score 92.45%. Limited trial with the help of 20 science student teachers gave out feasibility score 88.5% which also means this e-module is highly feasible to be used as learning resources.
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