Development of chemistry experimental module based on inventory research results on the use of secondary metabolites

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Abstract. The purpose of this study is (1) to conduct an inventory of research results using secondary metabolites that have been carried out by researchers, and (2) to develop a chemistry experimental module based on the inventory results. The research uses research and development (R&D) and survey methods. The research data was obtained through experiments, documentary studies, questionnaires. The analysis was carried out by the process of data reduction, presentation, conclusion, and data verification. The results showed that there are 30 references of the results research on the utilization of secondary metabolites used in the study. Those are used in some consideration, namely the results can be applied on a practicum scale, the tools and materials are cheap and easy to find, and most of the materials are local-natural resources. The percentage of the content and material design validation results in the modules are 80.2% and 86.2%, respectively, which are valid and feasible. Meanwhile, the results of the module practicality test on a small scale on 10 students as module users obtained a percentage of 80.8% and included in the good category.

1. Introduction
Research on the use of secondary metabolites has been carried out by experts. In the pharmaceutical field, secondary metabolites are widely used as anticancer, antidiabetic, antioxidant, antimicrobial, and anti-inflammatory. In the industrial sector, secondary metabolites are widely used as bioinhibitors in the corrosion process. One of the studies that has been done is analyzing the content of Tannin in guava leaves which is able to protect the iron surface from further corrosion events [1]. Meanwhile in the experiments of chemical laboratories, anthocyanin which is a secondary metabolite in plants can be used as an acid-base indicator [2]. In the process of natural food preservation, secondary metabolites are widely used as preservatives of fish and beef, including: utilization of wuluh starfruit [3] and garlic extract as meat preservatives [4]. Furthermore, in agriculture, secondary metabolites are also widely used as vegetable pesticides. The presence of secondary metabolites in weed plants can have the potential to be environmentally friendly natural pesticides [5]. In the application of Sensitized Solar Cell Dye (DSSC) which is one of the technologies for producing renewable energy by utilizing sunlight, secondary metabolites become one of the sensitizers (light sensitive) [6].

The benefits of secondary metabolites and their abundance both in the world and in Indonesia should be a consideration for the younger generation to study them. In an effort to arouse the curiosity of young researchers (students) about the potential of abundant secondary metabolites in Indonesian nature, an inventory of research results on secondary metabolites is needed. An inventory study that has been
explored can be used to develop a chemistry experimental module so that it enriches the repertoire of chemical recovery and arouses curiosity for young researchers and to improve the quality of chemistry lectures. The purpose of this study is to obtain information about the results of research using secondary metabolites that have been carried out by researchers. In addition, this study also aims to develop a chemistry experimental module based on natural materials.

2. Methods
This research was conducted in three stages, namely: 1) Preliminary stage consisting of theoretical and empirical studies to covering literacy about the utilization of secondary metabolites for development of research instruments and data collection to inventory research results using secondary metabolites, respectively 2) Module design phase which consists of module design process and design validation, and 3) Module development phase, which consists of module deployment and module validation. The stages of research are limited to the development stage. The testing and evaluation stages were not carried out. This study uses a qualitative descriptive research model by collecting data (survey). Data is obtained based on a literature review of the results of research on the utilization of secondary metabolites which are then in the inventory.

This study uses the Research and Development (R&D) Research design [7]. The R&D stages include: research and information gathering, planning, product design, initial or limited trials, major product revisions, wide-scale trials, operational product revisions, field trials, final product revisions, and dissemination. These stages can be summarized into four stages, namely information gathering and planning, product design, product development, and dissemination. This research is limited to the development stage, namely until the product revision section.

Data collection is done by using several techniques, namely, experiments, documentary studies, and questionnaires. To validate the chemistry experimental module, two teams of experts (validators) were employed (two lecturers from department of chemistry of University of Samudra) and two media/teaching material experts. Furthermore, glassware and chemicals were used for feasibility testing of each experimental module.

3. Result and Discussion
3.1. inventory in research results of using secondary metabolites
The preliminary stage in developing the practicum module is carried out through an inventory process. The inventory process is part of literacy studies about the use of secondary metabolites and empirical studies or data collection on research results using secondary metabolites. By means of Google scholar search engine, 213 articles were collected about the utilization of secondary metabolites, in range 2014 to 2019. Consisting of 107 national journal articles and 106 international journal articles. Articles obtained were grouped based on the types of utilization of secondary metabolites. The type of utilization of secondary metabolites is a reference for the development of the theme or title of each experiment in the experimental module. Data on journal articles are then reduced according to the provisions; (1) Type of used natural material which is local or easily obtained; (2) Experimental methods that can be applied in chemistry laboratories; (3) Tools and instruments commonly used in chemistry laboratories; and (4) Utilizing secondary metabolites one or several needs in various fields. An average of five journal articles on each trial theme is used as a reference and a source of reference in the development of natural materials based chemistry experimental modules. The summary of the results of the inventory of research results using secondary metabolites.
Table 1. Summary of Inventory in Research Results of Using Secondary Metabolites

| Theme of experiment       | Number of articles from international journals | Number of articles from national journals | Number of articles referenced |
|---------------------------|-------------------------------------------------|------------------------------------------|-------------------------------|
| Application to DSSC       | 15                                              | 17                                       | 4                             |
| Acid base indicator      | 15                                              | 15                                       | 8                             |
| Antioxidants             | 15                                              | 15                                       | 5                             |
| Antidiabetic             | 15                                              | 16                                       | 5                             |
| Preservative             | 15                                              | 15                                       | 5                             |
| Corrosion inhibitors     | 15                                              | 15                                       | 7                             |
| Biopesticides            | 17                                              | 13                                       | 5                             |

3.2. design of chemistry experimental module
Preparation of experimental modules is based on data obtained in the preliminary study. Preparation of the practicum module was also conducted by reviewing the feasibility of the experiment to be applied at the university level. In addition, the arrangement of module practices was discussed with several expert prior to validation. The selection of experimental material is adjusted to inventory data, student needs, and availability of tools and materials in the chemical laboratory. The following experimental titles of module have been developed are: (1) Efficiency of anthocyanin content for DDSC applications; (2) Anthocyanins as acid base indicators; (3) Anthocyanin activity as an antioxidant; (4) Antidiabetic activity of Centella asiatica L. leaf extract; (5) Use of plants as natural meat preservatives; (6) Effect and effectiveness of plant extracts as corrosion inhibitors; and (7) Nicotina tobacum L. extract as biopesticides.

The outline of the chemistry experimental module that has been compiled includes: (a) Cover (b) Preface, (c) Table of Contents, (d) general rules: duties and obligations of the practitioner, (e) laboratory equipments, (f) Experiment I to VII, and (g) Appendix. The contents of the experimental module for each experiment consisted of the experimental title, experimental objectives, introduction, tools and materials, experimental procedures, preliminary tasks, references, observation sheets and practical worksheets. The outline that has been made is then used as a reference for experimental module design. The drafting of the chemistry experimental module was carried out by the research team by utilizing the reference results of the inventory.
Figure 1. Cover design (a) draft of experimental module, (b) experimental module after revision

Figure 1 shows the cover of experimental modules before and after revisions. Change of cover is done according to the input of the validator on aspects of color use, spelling, and writing. Cover modules become more attractive and in accordance with the target object, namely students. Draft experimental modules which have been further designed are validated by experts.

3.3. validation of the chemistry experimental module
Learning tools developed can be qualify if it meet several criteria, such as validity and practicality [8]. Validation of module design includes components of module characteristics, module quality elements, and language. The summary of module design validity for each design component can be seen in figure 2.

Figure 2. Experimental module design validity percentage on each design component
Figure 2 show that the two validators gave a different assessment of the experimental module design. The highest percentage of design components is in the composition of module quality elements, namely aspects of format, organization, attractiveness, shape and size of letters, space, and consistency. Components of module and language characteristics according to the two validators are still low, so the practical module is revised according to the input and suggestions of the validator. In addition, the results of the questionnaire answers are also used as references in the module revision. The repaired modules are then given back to the validator for further discussion before being tested. The revision is complete if the validator has stated that the developed module is valid [9]. The revised experimental module design are the module cover, the addition of module boundaries, and binding.

The average percentage of module design before revision is 59%. The percentage increases after the revision process. The chemistry experimental module is declared valid and can be used in the learning process. Therefore, the revision of the experimental module design is only done once. Modules that have very high validity in aspects of language mean that the module is communicative, information clarity, in accordance with Indonesian spelling and using language effectively and efficiently. Modules developed using font type and size in accordance with the standards of assessment of learning materials, correct layout or layout, illustrations, images and photographs and designs appear clear and attractive as the guidelines for writing teaching materials [10, 12, 13]. In addition to the experimental module design, the content or material contained in the experimental module is validated by two experts in the field of natural chemical. The summary of module contents validity for each component can be seen in figure 3.

![Figure 3](image_url)

**Figure 3.** Experimental module content validity percentage on each design component

Based on figure 3, validation value for each component increases after revision. The results of the initial validation of the contents in the experimental module are 71%. After revision, it increased to 86% (valid). Based on the results of the answers on the questionnaire sheet, several improvements were made based on the input of the content expert validator, (a) adjusting the concepts in the experimental module to the requirements in the lecture, (b) adding pictures of tools and materials used, (c) adding practical report formats (c) add attachments on how to make reagents and phytochemical screening tests. Modules that have a very high category of content validity and feasibility aspects, namely: (1) in accordance with the demands of core competencies (2) module preparation according to student development; (3) the preparation of modules is in accordance with the learning material requirements; (4) modules have the
right material substance, (5) module content can add insight; and (6) module characteristics in accordance with moral and social values [10].

3.4. feasibility test of experimental module
The practicality test of the experimental module is done by applying practicum activities to 10 students. Then, students fill out a questionnaire to give opinions about the application of the practicum module that has been developed. Based on the percentage calculation, the value of 80.8% (good) is obtained. 5 out of 10 students strongly agree that the experimental module is very interesting and in accordance with the needs of the lecture. The results obtained is in good agreement with the research conducted on modules on learning other chemicals, Chemistry learning modules can improve student learning motivation better than other learning materials [12]. On the other hand, it can improve student learning outcomes in several concepts, such as in the topic of electrochemical analysis [14], hydrocarbons and derivatives [15], the concept of moles [16], chemical balance [17], and buffer solutions [18].

4. Conclusion
The results of the inventory, obtained 30 references to research on the utilization of secondary metabolites. Furthermore, on average there are 5 research references used as a source of experimental reference in the development of a chemistry experimental module, with consideration of the practicum scale, material used, and natural (local) material sources. The percentage of the content and material design validation results in the modules are 80.2% and 86.2%, respectively, which are valid and feasible. Meanwhile, the results of the module practicality test on a small scale on 10 students as module users obtained a percentage of 80.8% and included in the good category.

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