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From Seaweed to Chemicals: A Guide to Organic Compounds for Vocational High School Students

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ABSTRACT

This study aims to develop an organic compound textbook tailored for the Seaweed Agribusiness Expertise Program at vocational high schools. The research utilized a mixed-method approach based on the Model of Educational Reconstruction (MER), focusing on content structure analysis through literature review, subject matter clarification, and concept refinement. The resulting textbook features Problem-Based Learning (PBL) syntax and comprises four chapters integrating theoretical knowledge with practical seaweed applications. Expert validation was conducted to assess the alignment of learning objectives and compliance with the National Education Standards Agency (BSNP) criteria. The results confirmed the textbook's validity, with all indicators and learning objectives achieving a Content Validity Ratio (CVR) of 1.00, significantly exceeding the critical threshold of 0.622 for seven validators. Furthermore, the textbook demonstrated high feasibility based on BSNP standards, scoring 86.68% for content feasibility, 94% for presentation feasibility, and 100% for both language and graphics. In conclusion, the developed organic compound textbook meets validity criteria and is feasible for implementation in the Seaweed Agribusiness Expertise Program. This resource is expected to serve as a comprehensive reference for vocational students, significantly improving their understanding of organic compounds to support effective seaweed cultivation and processing practices.

Introduction

Seaweeds, the marine algae that thrive in our oceans, have long been recognized for their diverse array of chemical compounds, making them a rich and versatile resource (Klnc et al., 2013; Sari et

al., 2024). As the demand for natural, sustainable ingredients grows, these aquatic plants are gaining increasing attention from various industries, particularly in the fields of food, pharmaceuticals, and cosmetics (Doğan & Çelik, 2023; Ito & Hori, 1989). Seaweeds, commonly referred to as macroalgae, have garnered significant attention in recent years due to their diverse chemical composition and versatile applications across numerous industries, including food, cosmetics, and pharmaceuticals (Yong et al., 2016). The chemical composition of seaweeds is remarkably complex, comprising an array of carbohydrates, proteins, lipids, minerals, vitamins, and a plethora of bioactive compounds (Ito & Hori, 1989; Jiao et al., 2011). These diverse compounds endow seaweeds with a wide range of functional properties, rendering them valuable in numerous applications (Klnc et al., 2013).

Vocational High Schools are part of an education system that specifically helps students prepare for the world of work. Vocational school is expected to support economic growth around the area where the school is located. Therefore, Vocational high school is required to be able to produce graduates who are ready to work to meet the needs of the business world or the industrial world, so it is necessary to prepare vocational school graduates who are competent in their fields, education and income level as well as ethnicity (Birch et al., 2019; Davis, 2011; Siswantari, 2012). Thus, a strong vocational program must be tightly aligned with the current and projected needs of the relevant industries (Jaedun et al., 2020).

Seaweed is a versatile and underutilized resource that holds significant potential for integration into vocational chemistry education. Studies have demonstrated the nutritional and bioactive properties of various seaweed species, highlighting their potential as a valuable teaching tool (Ito & Hori, 1989; Liu et al., 2016). As vocational high school students explore the world of organic chemistry, the study of seaweed-derived compounds can serve as a captivating and relevant case study. By delving into the diverse chemical structures and functionalities of these marine-based molecules, students can gain a deeper appreciation for the interconnectedness of the natural world and the potential applications of organic chemistry in addressing real-world challenges. Exploring the rich chemical diversity of seaweeds and their bioactive compounds can inspire students to consider innovative solutions to environmental and societal issues, bridging the gap between theoretical knowledge and practical applications. Through hands-on experiments and engaging lectures, students can investigate the extraction, characterization, and potential applications of seaweed-derived compounds, fostering their understanding of organic synthesis, analytical techniques, and the importance of sustainable resource utilization (Cotas et al., 2023; Liu et al., 2016; Sanjeewa et al., 2016).

Vocational school

One of the vocational school expertise programs, previously better known for student productivity, is Seaweed Agribusiness. Seaweed agribusiness is one of the expertise programs contained in aquaculture by the Indonesian National Work Competency Standards (SKKNI). The subject group of the expertise program consists of several subjects grouped based on expertise competencies and expertise competencies. This expertise program aims to acquire knowledge and skills in aquaculture techniques, seaweed processing, and marketing of seaweed processing products.

The results of observations at one of the vocational schools with the ARL expertise program located in Takalar district, South Sulawesi, found a problem: the content of the chemistry subjects provided was not directly related to the needs of the expertise program subjects. It can be seen from the findings of the observation results, namely, (1) there are no standardized chemistry books for the vocational schools seaweed agribusiness expertise program. This is supported by the results of previous research which revealed that for Vocational Schools, the Seaweed Agribusiness Program still uses general chemistry books with additional seaweed-specific material (Purwadi et al., 2018; Sari, 2014; Sumantri et al., 2017); (2) most teachers in vocational school still teach chemistry material like high school material; (3) the chemistry material taught to students has not been able to support and equip life skills for student expertise programs. This research is supported by other facts found in almost all vocational schools, namely chemistry textbooks for technology and engineering, health, and agriculture expertise programs using the same teaching materials, especially textbooks (Sari, 2014; Sari et al., 2024).

State-of-the-art of this research are educational approaches in organic chemistry and seaweed-based innovations. Various pedagogical strategies have been developed to enhance the teaching of organic chemistry, including the use of contextual and experimental approaches. These methods aim to make the subject more accessible and engaging for students (Li & Eilks, 2021; Pernaa et al., 2025). Also, Seaweed is recognized for its potential in creating biodegradable and eco-friendly materials, such as edible films for food packaging. These materials are not only sustainable but also possess enhanced properties due to the incorporation of bioactive compounds (Ebrahimzadeh et al., 2023). Based on the literature review and state-of-the-art, gaps in research and application for Vocational High Schools seaweed agribusiness expertise program are limited exploration of seaweed in education. While seaweed's industrial applications are well-documented, its integration into educational curricula, particularly for vocational training, remains underexplored. There is a

need for more comprehensive educational resources that leverage seaweed's chemical properties (Ioannou & Roussis, 2009; Merkel et al., 2021).

The emphasis of vocational school chemistry in technology and engineering expertise should not be the same as in health and agricultural expertise (Istriningsih et al., 2022). It does not follow the vocational high school curriculum, where different expertise programs will require different chemical material debriefings. To overcome these problems, it is necessary to develop relevant textbooks that can equip life skills, bridge, combine experience and knowledge according to needs, and can be reached (accessible) by students (Toharudin et al., 2011). Textbooks contain knowledge derived from Basic Competencies in the curriculum (Andi, 2012). By delving into the connections between seaweed-derived organic compounds and their real-world uses, students can gain a deeper appreciation for the field of organic chemistry and its importance in various industries (Carey, 2022; Miller, 1988; Wackerly et al., 2024).

Integration of Seaweed in Vocational Education as introducing seaweed as a source of organic compounds in vocational high school curricula could provide students with practical insights into sustainable chemistry and marine biology (Venkatesan et al., 2024). This approach could foster innovation and interest in green chemistry practices. Besides that, Morais et al. (2021) Seaweed's diverse applications, from cosmetics to food packaging, highlight its potential as a teaching tool that bridges multiple disciplines. This could enhance students' understanding of the interconnectedness of scientific fields. This encouraged researchers to develop teaching materials with reference to SKKNI by collaborating with teachers, chemistry content experts, and learning media experts (Bou et al., 2023; Iqbal, 2021).

Model of Educational Reconstruction (MER)

The Model of Educational Reconstruction (MER) is one of the developments of teaching models, sequences, and teaching materials developed by Duit, Gropengieber, and (Duit et al., 2012). This MER model has been used as an alternative research model in the international world, including by Laherto (2012) in his dissertation by introducing nanoscience technology to informal teaching. The main characteristics that distinguish the MER model from other development models are teaching materials (the main issue of science) sourced from socio-scientific issues, student learning needs, and teacher abilities must receive the same attention to improve the quality of teaching and learning (Duit, 2007). In addition, the basic idea of MER is that the structure of content for teaching cannot be taken directly from the structure of science content but must be specifically rebuilt with due regard to educational objectives (Duit, 2007; Duit et al., 2012).

The Model of Educational Reconstruction (MER) offers a structured approach to designing chemistry learning that bridges the gap between students' existing understanding and scientific concepts. It begins with analysing students' preconceptions about a particular topic and the scientifically accepted understanding. This analysis reveals discrepancies and identifies areas where students' intuitive notions might conflict with scientific principles. The next stage of MER involves carefully reconstructing the scientific content to align with students' learning needs. This reconstruction often involves simplifying complex ideas without sacrificing accuracy, using analogies and real-world examples to make abstract concepts more concrete, and designing learning activities that challenge students' existing mental models and encourage them to build more sophisticated understandings (Nursa'adah et al., 2018; Yusmaita & Nasra, 2018)

The resulting textbook must have quality standards. Textbook standards are the basis for determining the quality of the textbooks produced. According to BSNP, Indonesian standard of education (2009), the assessment of the quality of textbooks must pay attention to material content, presentation of material, language, and book graphics.

Based on the background and identification of the problems that have been stated, the problems to be studied in this research are:

1) How is the construction model of organic compound textbooks based on vocational expertise programs majoring in Seaweed Agribusiness (ARL)? , and

2) How is the expert assessment of the design of organic compound textbooks based on skill programs in vocational high schools expertng in seaweed agribusiness?

Method

This research used a combination research method (mixed methods) (Creswell, 2017; Brown & Green, 2019) with the Model of Educational Reconstruction (MER), which was focused on the content structure analysis component (Duit, 2012). The subject of the study was teaching materials in the form of organic compound textbooks based on content studies from chemistry textbooks both for universities and for high schools and textbooks and journals related to the Seaweed Agribusiness (ARL) expertise program. Data sources were expert lecturers, chemistry teachers, and expert program teachers. This study consists of two stages including that shown on figure 1:

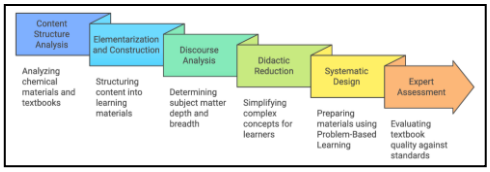

Fig 1: Development and Assessment of Educational Content

1. Content Structure Analysis

The analysis was carried out to analyze the content of chemical materials and materials of the ARL expertise program on chemistry and seaweed textbooks, as well as supporting journals. The analysis was conducted to determine the material's scope and the demands of cognitive abilities. There were two stages in designing the structure of science content into a learning content structure, namely elementarization and construction. MER did not provide detailed steps in carrying out elementarization and construction.

Therefore, for the stages of elementarization and construction, discourse analysis and didactic reduction were carried out. Discourse analysis was adapted from Sihotang et al. (2020) through Pedagogic Subject Matter to determine the depth and breadth of the subject matter. The didactic reduction was adapted from (Anwar et al., 2021) to reduce the difficulty of the concept. Meanwhile, the systematic design of material preparation (outline of Principles Formulation of Guidelines) was made using the Problem-Based Learning (PBL) stages suitable for vocational school students.

From the analysis of the content structure, data was obtained in the form of the original text, which was the result of translation of textbooks and journals consisting of essential concepts, and basic texts, which were the result of clarification, modification and completion of concepts, as well as outlines of textbooks

2. Expert assesment

From the analysis of the content structure, data was obtained in the form of the original text, which was the result of translation of textbooks and journals consisting of essential concepts, and basic texts, which were the result of clarification, modification and completion of concepts, as well as outlines of textbooks. Furthermore, the organic compound textbook was validated by several experts, consisting of 1 lecturer with expertise in teaching material development to assess the pedagogical quality of the textbook (Gregori-Giralt & Menéndez-Varela, 2021; Maptuhah et al., 2023), 2 organic chemistry lecturers to assess the accuracy and depth of chemical material relevant to seaweed cultivation and processing (Kerton & Yan, 2017; Qu, 2019), 2 teachers of the Seaweed Agribusiness program to assess the relevance of textbook material to the needs of the workplace, the suitability of the vocational high school curriculum, and the practical application of chemical concepts in seaweed cultivation and processing (Purwadi et al., 2018). Expert assessment also involved 2 chemistry teachers from vocational schools to assess the depth and breadth of the material, as well as the effectiveness of examples and exercises in the textbook (Anwar et al., 2021). Assessment of textbooks is carried out in stages, including 1) the suitability of learning indicators

and objectives, 2) validation of textbook texts, and 3) BNSP standards for textbooks.

Quantitative data is obtained from the results of expert assessment using an assessment sheet related to the suitability of indicators and learning objectives in the cognitive aspects of organic compound material that will support the expertise program material. Furthermore, an assessment is made of the suitability of learning objectives with the text design in the textbook. The data analysis technique in this study uses descriptive *Content Validity Ration* (CVR). Wilson et al., (2012) and Jeldres et al,. (2023), in the analysis of the calculation of the CVR_{table} value, obtained a new value for the CVR_{table}, which is a new reference from the Lawshe (1975) CVR_{table}. The resulting textbook must have quality standards. Textbook standards are the basis for determining the quality of the textbooks produced. According to Badan Standar Nasional Pendidikan (BNSP), the assessment of the quality of textbooks must pay attention to material content, presentation of material, language, and book graphics. The data from the format of the suitability of the textbook with the BNSP is analyzed by calculating the value of each item aspect that is assessed using the rating scale technique and then interpreted qualitatively. The textbook assessment format can be seen in Table 1.

Table 1. Textbook Assessment based on BNSP criteria

No	Aspects assessed	Criteria
1	Feasibility of Content a) Material b) Substance correctness c) Exercises and assignments	a) Materials support the achievement of basic competencies; consider student abilities; support expertise programs; consider the social environment; and are up to date with the latest developments in chemistry. b) Concepts and definitions are presented accurately according to the field of chemistry by including each reference in the bibliography, examples and cases with insights into the expertise program, and actual images/diagrams/illustrations with the latest references to enrich the material c) Exercises and assignments are appropriate to the chemistry material, not too easy or difficult, varied to encourage students to think critically, logically, systematically, and analytically, support the expertise program, and are relevant.
2	Feasibility of presentation a) Systematics b) Completeness	a) The system of each chapter in the textbook is consistent with the sequence according to the learning objectives; the presentation starts from simple concepts to complex concepts, easy concepts to difficult concepts, and from concrete concepts to abstract concepts. b) The completeness of the presentation includes a preface, table of contents, macro structure, basic competencies, learning objectives, core material, sample questions, and evaluation.
3	Languange	Compliance with the Indonesian EYD, guidelines is simple, communicative, organized, systematic, and effective.
4	Graphics	Appropriate font, typeface, spacing, layout, illustrations, images or captions, color combinations, placement, and size of tables and images.

(Yu et al., 2022; Gumiral & Ismail, 2023; Yuliani, 2024)

Result and Discussion

1. Characteristics of Organic Compound Textbooks SMK Seaweed Agribusiness Expertise Program (ARL)

The fundamental idea underlying the construction of organic compound textbooks for vocational ARL expertise programs using the Model of Educational Reconstruction (MER) was that the content structure for lessons could not be taken directly from the structure of science content but specifically reconstructed (re-construction) (Duit et al., 2012).

Textbooks were systematically organized based on certain instructional objectives based on the applicable curriculum. Instructional objectives included learning indicators and objectives. Learning indicators and objectives were markers of the achievement of Basic Competencies. After the indicators and objectives were formulated, validation was undertaken to find out how the indicators were compatible with basic competncies and the conformity of the indicators to the learning objectives. Core Competencies and Basic Competencies for vocational high school expertise programs were described from the 2013 curriculum following the Regulation of the Minister of Education and Culture number 70 of 2013.

Based on the validation results, there were 24 indicators and 33 learning objectives declared valid with a calculated Content Validity Ratio (CVR) value greater than the CVR value of the table (Wilson et al., 2012).

The characteristics of textbooks developed with the Model of Educational Reconstruction (MER) based on Problem-Based Learning (PBL)

- *Outline textbooks using Problem-Based Learning (PBL) syntax*

The theoretical framework for making textbook outlines in the Model of Educational Reconstruction (MER) as per the theory of constructivism (Duit et al., 2012). In learning activities on the theory of constructivism, students actively built science based on their initial knowledge. Problem-Based Learning (PBL) was one of the appropriate learning models for developing textbook outlines based on the theory of constructivism. In addition, PBL was also very much in line with the 2013 curriculum and Merdeka curriculum, which used a scientific approach (scientific method).

The stages in the textbook outline used the Problem-Based Learning (PBL) syntax developed by (Arends & Kilcher, 2010). Learning began by introducing problem situations and presenting and analyzing work results. The PBL stage wsas in accordance with the characteristics of SMK students, where chemistry subjects were integrated to support the subjects of the identical expertise program by producing a work related to the expertise program they were engaged in. Figure 2 outlines the

organic compound textbook for vocational school of seaweed agribusiness expertise program based on the PBL stages.

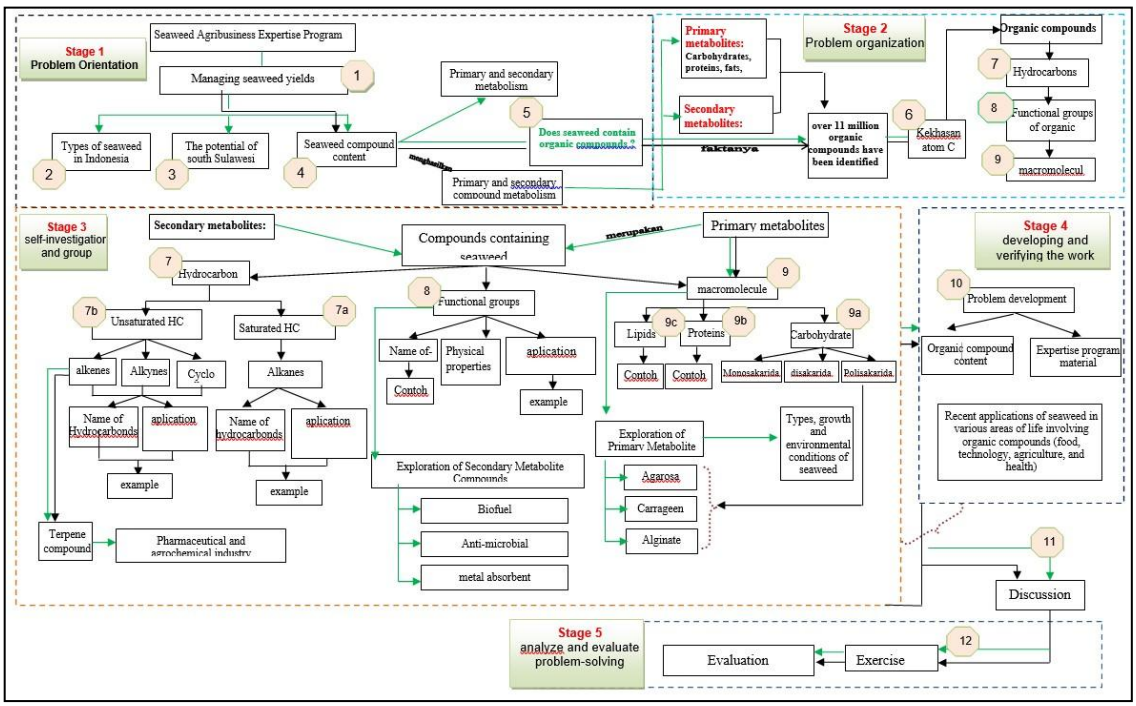

Fig 2**:** Outline textbooks according to the Stages of Problem-Based Learning

Based on the outline of the textbook in figure 1, stage 1 of problem orientation begins after the student is confronted with a problem structure that is authentic in nature so that students know why they should study the teaching material. Information will be collected by students and help them analyze the purpose of solving the problems they face in digital age (Boss & Krauss, 2022). This aligns with the core principles of PBL (Smith et al., 2022), where learning is driven by real-world problems by understanding the practical applications of the material, students are motivated to learn (Zai et al., 2024) also underscores the importance of engaging learning environments, contrasting traditional, passive learning with interactive methods.

Stage 2 of problem organization directs students to search for and compile a frame of mind for solving problems. The problems presented in the textbook setting are organized in a certain form and focus and are a stimulus for students. With the knowledge they have gained from various sources, it is hoped that students can solve problems, such as organic compounds in seaweed and why they are found in life. Teacher can strengthen stage 2 and better equip students to effectively navigate the complexities of problem-solving in the context of seaweed agribusiness and organic chemistry. Providing support for collaboration and the use of authentic resources can make this

stage a powerful catalyst for deep learning (Dolmans & Gijbels, 2013; Wardono et al., 2018).

Stage 3, self-investigation and group. At this stage, exploration and data collection in the form of deeper information is carried out to create and build student ideas to arrive at problem-solving (Rofik et al., 2025). Students are expected to learn from the world of knowledge and accumulate expertise through existing problems. Independent or group studies obtain new information related to the problems studied. Stage 4 is developing and verifying the work. Students are invited to create written works on the organic compound and seaweed agribusiness expertise program materials. Stage 5, analyze and evaluate problem-solving. The textbook contains practice questions and evaluations to measure *students'* understanding at this stage. The questions given differ from the widely circulated chemistry textbooks, which are directed to support the seaweed agribusiness expertise program (Pertiwi et al., 2024).

- *Components of the Organic Compound Textbook Seaweed Agribusiness Expertise Program (ARL)*

The design in the organic compound textbook for vocational school of seaweed agribusiness expertise program predominantly used green according to the seaweed agribusiness expertise program material for vocational school students, which was closely related to the environment and nature. The organic compounds textbook for vocational school of seaweed agribusiness expertise program consisted of four chapters: introduction to organic compounds, hydrocarbons, functional groups of organic compounds, and macromolecules. In textbooks, the title of each chapter was written using capital letters with a letter size of 14. The content of each chapter contained basic competencies and learning objectives, a brief description of the chapters, materials, supplementary reading lists, practice questions and evaluations. Each chapter was preceded by learning objectives that students were expected to achieve.

To support students' insight into organic compound materials and Seaweed agribusiness expertise programs, in the textbooks, there were sections related to the expertise program in the form of additional knowledge, information, and seaweed applications in terms of various aspects. With parts related to this expertise program, it was hoped that it could help improve the expected competencies. In addition, chemical materials, especially organic compounds, could be relevant to the needs of students of the ARL expertise program to attract students' interest and motivation to learn them. Figure 3 is an example of a section related to the seaweed agribusiness expertise program.

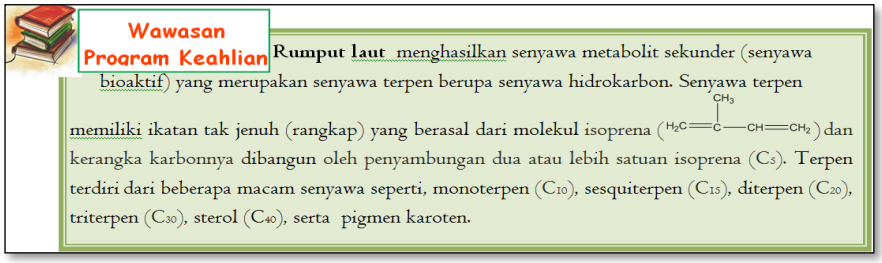

Fig 3: View of Expertise Program Insights in Textbook

The expertise program insights column may also contain applications of seaweed in various areas of life, such as in figure 4.

Fig 4: Display of seaweed applications in textbooks

In addition to the expertise program insights column, some columns contain information, such as the "did you know?" column in figure 5.

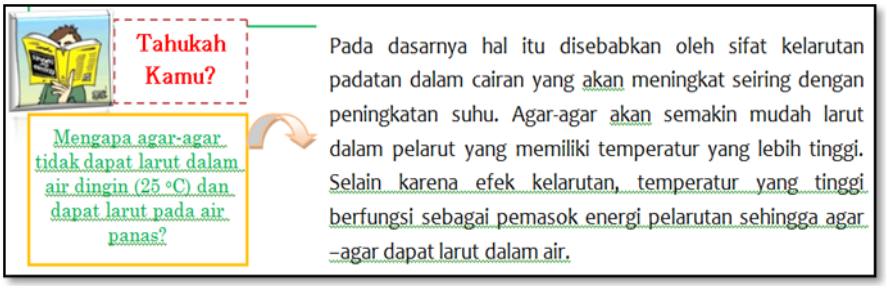

Fig 5: Information Displayed in textbooks

It is hoped that the existence of information columns, expertise programs, and seaweed applications as subject matter for expertise programs will strengthen their understanding of organic compounds so that students can build and associate concepts with each other so that they can support expertise program subjects and equip life skills related to the seaweed agribusiness expertise program that students are engaged in.

2. Expert Assessment of Organic Compounds Textbooks of Seaweed Agribusiness Expertise Program.

- *Validation of the suitability of learning objectives with the textbook text*

Expert assessment of organic compound textbooks for vocational high school students of the ARL expertise program was conducted by validating the suitability of learning objectives with the texts in the textbooks. The assessment of the suitability of learning objectives with textbook texts was conducted by experts consisting of three chemistry lecturers, two chemistry teachers, and Two seaweed agribusiness expertise program teacherds. The text in the textbook was by the learning objectives. It can be seen from the acquisition of the CVR value = 1.00. The CVR value of 1.00 indicates perfect convergent validity, meaning the experts' assessments completely agreed that the textbook content matched the learning objectives. This signifies a high degree of alignment between what the textbook aims to teach and what it actually covers (Yu et al., 2022). This is aligned with the results of Hailikari et al. (2022) that the importance of alignment between learning objectives and testing materials to support active learning. Some suggestions were obtained, and many parts needed to be improved. Corrections and suggestions from these validators were used as a reference to improve the content of the material in the textbook so that the resulting textbook had a correct, interesting concept and was by the ability of SMK students to understand it. Some improvements based on expert assessment on the suitability of learning objectives with textbook texts from experts.

- *Assessment of the suitability of textbooks with BSNP* criteria

The results of processing the score of the assessment of the suitability of textbooks that have been prepared with BSNP based on expert judgment are presented in Table Figure 6.

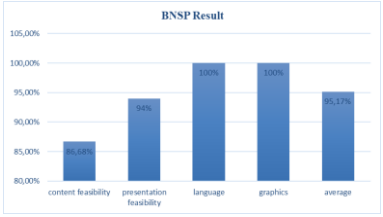

Fig 6: Diagram of Percentage Score of Textbook Conformity with BSNP

The highest percentage score from Figure 6, 100%, was achieved in both language and graphic design aspects. A 100% score for language indicates that all language components within the organic compound textbook based on the ARL vocational program, such as the use of EYD, sentence structure, material explanation, ideas, consistent use of terminology, and effective sentences, meet the standards of a good textbook according to BSNP. Similarly, the 100% score for graphic design indicates that all graphic components of the organic compound textbook based on the ARL vocational program, such as shape, font type, spacing, layout and typing, illustrations, images or captions, usage and placement, as well as the order of tables and figures, have been implemented consistently and in accordance with the standards of a good textbook according to BSNP standart.

Conclusion

Based on the results of the study, it can be concluded that the typical characteristics of organic compound textbooks for vocational high school seaweed agribusiness expertise programs included outline textbooks using Problem-Based Learning (PBL) syntax, consisting of four chapters, and there were parts related to the expertise program in the form of knowledge, information, and application of organic compounds contained in seaweed. The results of the expert assessment of textbooks included the suitability of indicators with learning objectives and the suitability of learning objectives with textbook texts obtained that all indicators and learning objectives had a calculated CVR value above the critical CVR value of 0.622 for seven validators, namely, CVR = 1.00 so that it can be accepted or declared valid.

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