Enhancing Students' Higher-Order Thinking Skills through the Implementation of a Scientific Approach to Hydrocarbons

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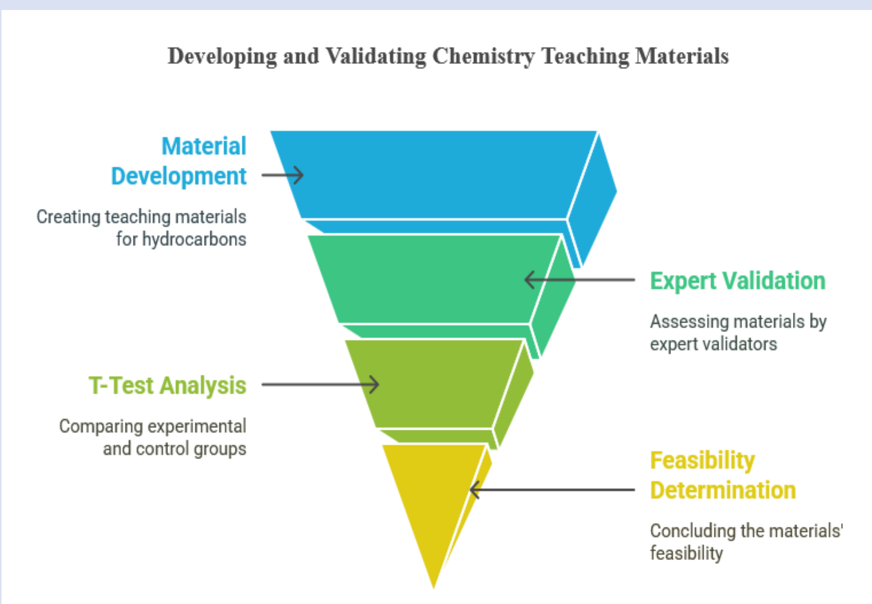
Abstract

This research focuses on improving students' higher-order thinking skills (HOTS) in hydrocarbon chemistry by developing teaching materials grounded in a scientific approach. To assess the effectiveness of the learning described above, this research employs a mixed-methods approach, collecting observational data and administering questionnaires to high school students at SMAN 1 Paiton, Probolinggo Regency. In practice, this research produces teaching materials on hydrocarbons developed using a scientific approach and assessed by expert validators. The average suitability scores are 91.06% for teachers' books and 91.72% for student books, both rated as very feasible. Furthermore, the independent-samples t-test revealed a significant difference between the experimental and control classes ($p = 0.012$; <0.05). Qualitative findings also indicate that the use of these teaching materials is highly feasible and necessary to improve HOTS among students.

Graphical Abstract



Keywords:

Teaching instrument; High level of thinking; Chemistry teaching; 21st century skill; scientific reasoning

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Introduction

In practice, the quality of learning is essentially an important part of achieving learning goals, thus the occurrence of various changes in learning activities is intended to improve students' understanding and skills, especially in Chemistry learning activities that not only require inductive thinking but also deductive thinking about a discussion, by finding answers to a question; what, why and how the process of change occurs related to the composition, structure, properties, dynamics and energetics of substances that accompany the nature of change, especially hydrocarbon material in chemistry lessons (Giovany et al., 2022).

In addition, chemistry is understood as a science that studies the composition, structure, and energy changes that accompany transformations in substances (Saija, Rahayu, Fajaroh, 2022). Based on this view, skills and reasoning are needed for students in Chemistry learning (Kurniawan, Rahayu, Fajaroh, & Almuntasheri, 2020., Law, 2021). In this context, Chemistry learning is an important part of building high-level thinking skills, so that it can then improve and develop soft and hard skills, this is in accordance with the characteristics of the Merdeka curriculum, a form of developing critical and higher-order thinking skills in the Chemistry learning process, specifically focused on hydrocarbon material, according to observations from several high schools in Probolinggo Regency, that hydrocarbons are learning materials that are considered very for students to understand, especially for SMAN 1 Paiton.

Thus the level of difficulty in learning above is caused by several aspects including learning motivation, intelligence level, traditional learning models and methods, as explained by Ali Azmi in his research that, learning motivation is an important part of learning activities and is understood as a supporting factor to improve students' understanding in mastering learning materials, especially on hydrocarbon material so that they can then distinguish between saturated hydrocarbon compounds and unsaturated hydrocarbon compounds.

In addition, the difficulty of students' understanding of hydrocarbons in chemistry learning may be caused by a decrease in their critical thinking skills, even though the material requires strong memory and logic, and this is based on the nature of hydrocarbon which are abstract with a very small molecular size, so that it is difficult to understand (Rahmi & Ilham, 2014). On the other hand, the learning methods used are still conventional, so students do not fully understand the material, as can be seen from the results of daily tests of students at SMAN 1 Paiton, which is only 22.8% or 8 out of 35 students who meet the minimum completion criteria, with an average score of 68.8%. In addition to these problems, the difficulty students face in understanding hydrocarbons stems from the limited availability of teaching materials, which hinders discussions of hydrocarbons.

Therefore, the discussion of hydrocarbons is both concrete and abstract at the molecular level. In other perspective, students' thinking skills do not develop on their own; rather, they develop through their learning experiences. Therefore, chemistry instruction should incorporate multiple components to develop students' thinking skills. Consequently, the discussion of hydrocarbons requires higher-order thinking skills (HOTS), guided by a scientific approach that involves continuous observation, inference, clarification, prediction, measurement, questioning, interpretation, analysis, and synthesis (Lederman, 2013). So that the nature of science (NOS) can be understood.

In this context, the scientific approach to learning aims to address various problems and ultimately to build a framework of critical and scientific thinking regarding the nature of science, which encompasses philosophical, sociological, and historical studies of this knowledge. The discussion of NOS is more epistemological about knowledge; this is in accordance with the nature of science itself, which is tentative. Given the above problems, particularly the difficulties students face in understanding hydrocarbon materials in chemistry, a scientific model is needed to train and develop HOTS and to be practically implemented through the development of teaching materials. Several studies have developed teaching material for helping chemistry and science teachers to design suitable teaching (Lailia, 2025; Qomaliyah & Habiddin, 2025; Rofik et al., 2025). Therefore, this study aims to assess the feasibility of using chemistry teaching materials developed through a scientific approach to improve higher-order thinking skills, particularly among students at SMAN 1 Paiton, Probolinggo.

Method

This research can be categorised as a type of research and development study. It aims to produce chemistry teaching materials using a scientific approach to foster and develop a framework of HOTS. Therefore, the development of hydrocarbon teaching materials in chemistry lessons, using the Borg and Gall model, which includes several aspects, including potential problems, data collection, product design, design validation, design revision, initial trials, product revisions, usage trials, and mass production, can be described in Figure 1.

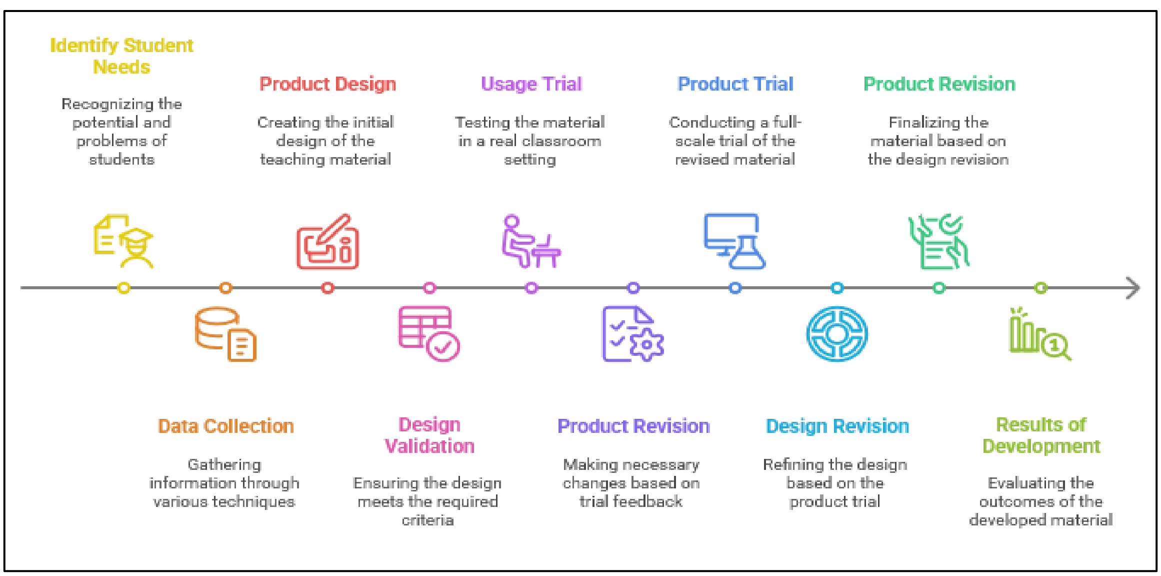

Figure 1. Teaching Material Development

Based on the steps outlined above, the validation and assessment process can be conducted by lecturers from FMIPA UM and 8 chemistry teachers from Senior High Schools in Probolinggo Regency. The trial subjects consisted of 6 students from class XII IPA 1 SMA Negeri 1 Paiton, and the field trial was limited to two classes, XI IPA, at SMA Negeri 1 Paiton. Data collection techniques can include the following; a) curriculum documentation, achievement of learning outcomes and learning resources, b) distribution of questionnaires, including validation of teaching materials, comment sheets and various suggestions from validators, with assessment criteria consisting of content feasibility, data presentation feasibility and language feasibility, using a Likert scale of 1 to 4, c) Posttest, conducted through experiments using the teaching materials, so that the learning outcomes of students can be known (Patton, 1980).

The data analysis technique used is quantitative, with descriptive analysis. The assessment results from the validation questionnaire and the student response questionnaire are summarised and presented as percentages using SPSS 20.0 for Windows. If the results obtained meet the minimum criteria for feasibility, the developed teaching materials can be tested; if they do not meet the criteria, revisions are made (Biklen, 1998).

Results & Discussion

The discussion on the development of hydrocarbon teaching materials was presented through data presentation and data analysis by presenting teaching material trial data in the form of assessments, comments, suggestions and analysis from content and learning material expert validation data, learning media validation, individual trials, and field trials carried out according to the teaching material trial implementation schedule. The results of the teaching material validation by the validators are presented in Table 1.

Table 1. Assessment of Student Book by Expert Validators

No	Description	Validator 1		Validator 2	
		Score	Criteria	Skor	Score
1	Contents	89.60 (%)	Very worthy	86.50 (%)	Very worthy
2	Linguistics	82.92 (%)	Very worthy	82.30 (%)	Very worthy
3	Serving	89.60 (%)	Very worthy	89.10 (%)	Very worthy
4	Graphics	87.50 (%)	Very worthy	86.70 (%)	Very worthy
Average value		87.41 (%)	Very worthy	86.15 (%)	Very worthy

As shown in Table 1, the assessment of the student book teaching materials by two lecturers, as expert validators in learning, yielded a content eligibility of 89.60%, and the assessment by 8 high school teachers, as expert validators of the content of the learning material, was 86.50, both meeting very worthy criteria. The assessment of the linguistic aspect by lecturers was 82.92, and by eight teachers it was 82.30, both with very valid criteria. In addition to linguistic aspects, the assessment of the presentation in the student book by two lecturers was 89.60%, and by eight teachers it was 89.10%. The assessment of the graphics in the student book by two lecturers was 87.50%, and by eight teachers it was 86.70%. The average assessment of the student book by SDA was 87.41%, and eight teachers rated it 8615%, indicating that the teaching material was highly feasible for use in learning activities. Thus, the assessment results of teacher book teaching materials, evaluated by 2 lecturers and 8 high school teachers serving as expert validators, are presented in Table 2.

Table 2. Evaluation of the Teacher's Book by Content Expert Validators

No	Description	Validator 1		Validator 2	
		Score	Criteria	Skor	Criteria
1	Contents	91.70 (%)	Very worthy	84.38 (%)	Very worthy
2	Linguistics	88.30 (%)	Very worthy	83.13 (%)	Very worthy
3	Serving	85.40 (%)	Very worthy	89.58 (%)	Very worthy
4	Graphics	85.00 (%)	Very worthy	87.31 (%)	Very worthy
Average value		87.60 (%)	Very worthy	86.10 (%)	Very worthy

Based on the table above, the results of the assessment of the teaching materials in the teacher's book, conducted by two lecturers as expert validators, show a content eligibility of 91.70%, and the results of the assessment by 8 high school teachers, as expert validators of the material, are 84.38%, with very feasible criteria. While the assessment of language by one teacher is 88.30%, and by eight teachers is 83.13%, with very valid criteria. In addition to language, the presentation in the teacher's book was assessed by two lecturers at 85.40% and 89.58%, and the graphics in the teacher's book were assessed by two lecturers at 85.00% and 87.31%. Thus, the average assessment of the teacher's book by two lecturers is 87.60%, and by eight teachers is 86.10%, indicating that the teaching materials are highly feasible for use in learning activities.

Table 3. Assessment of the Student Book for Each Topic

No	Rating Result	Teacher's Book		Student Book	
		Score	Criteria	Score	Criteria
1	First Course Presentation (%)	90.10	Very worthy	91,50	Very worthy
2	Learning Activities 1 (%)	90.20	Very worthy	89,28	Very worthy
3	Learning Activities 2 (%)	91.00	Very worthy	92,4	Very worthy
4	Learning Activities 3 (%)	88.90	Very worthy	90,28	Very worthy
5	Learning Activities 4 (%)	95.00	Very worthy	95,33	Very worthy
6	Learning Activities 5 (%)	88.89	Very worthy	89,89	Very worthy
7	Learning Activities 6 (%)	95.21	Very worthy	95,10	Very worthy
8	Learning Activities 7 (%)	89.20	Very worthy	90,00	Very worthy
	Average value	91.06	Very worthy	91,72	Very worthy

Thus, the assessment results of learning activities of learning activities 1 to 8 show that the concept is very valid, and this shows that there are no errors in the substance of the material, so that the teaching materials above have the appropriateness for basic chemistry competencies, have the truth of the material substance, according to student needs, according to the needs of teaching materials and the value of benefits to increase more contextual knowledge. The percentage data indicate that the teaching materials listed above are highly suitable for use in learning activities. Table 3 shows that the assessment of the initial presentation of the teacher's book section is 90.10% (very suitable), and that of the student's book is 91.50% (very suitable). This indicates that the teaching material is well-suited to learning activities. Because the initial part of this teaching material contains the cover, table of contents, instructions for using the materials (for both teachers and students), and concept maps. The assessment of the initial presentation of the teaching materials indicates a rating of very suitable, indicating that the initial part of the teaching material can be presented easily, interestingly, effectively, and efficiently (Krathwohl, 1973).

The overall assessment included initial appearance, appropriateness of content, presentation, language, and graphics. The teacher's book averaged 91.06%, while the student's book averaged 91.72%. These high scores indicate highly engaging materials that motivate students and stimulate curiosity. The attractive design, effective font choices, compelling illustrations, and use of colour engage readers' interest. The language adheres to standard Indonesian rules and is communicative, interactive, and efficient. The validator's comments were general, but the content is highly appropriate, with only a few sections needing revision for the draft development (Bloom, 1956). Thus, the readability assessment of the teacher’s book above encompasses content suitability, language, presentation, and graphics. The results of the readability assessment, based on the suitability determined by BSNP, are presented in Table 4.

Table 4. Teacher Book Reading Trial Results

No	Rating result	Validator Assessment Results								Average	Criteria
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**		
1	Learning Content (%)	95	95	95	88	89	90	91	92	91.88	Very worthy
2	Linguistics (%)	81.25	87.5	92	89	88	90	91	89	88.47	Very worthy
3	Serving (%)	98	90	95	93	92	98	91	90	93.38	Very worthy
4	Graphics (%)	91.67	100	98	97	92	96	90	91	94.46	Very worthy
Average value		91.48	93.125	95	91.75	90.25	93.5	90.75	90.5	92.04	Very worthy

Table 4 shows that the results of the feasibility of the teaching material components obtained an average score of 91.88%, and it is stated that the teaching material is very feasible to use, because it is supported by several supporting components including, clarity of material, the approach used and supporting factors in the teaching material including the presentation of contextual images, with the results of the overall teaching material assessment, the average assessment of the teacher's book readability test by the chemistry teacher validator obtained a result of 92.04% with very feasible criteria, and it can be concluded that the teaching material in the form of a teacher's book is very feasible to use in chemistry learning activities. The results of the individual-trial subject assessment for the draft teaching material are presented in Table 5.

Table 5. Student Book Readability Test Results

No	Rating result	% Average	Criteria
1	Components of teaching materials	84,72	Good
2	Appearance	94,17	Interesting
3	Language used	81,25	effective
4	Graphics of teaching materials	84,03	Interesting
Average		85,80	Very nice and good

Based on Table 5, six trial students rated the teaching material component at 84.72%, which falls within the very good category. This indicates the material offers a clear description, concept maps, and engaging preliminary activities that stimulate students' curiosity. The overall average rating given by the test subjects was 85.80%. This confirms that the material, presentation, language, and graphics are highly suitable for learning activities

Results of the Effectiveness Test of Teaching Material Development

The results of the effectiveness test of this teaching material were obtained by calculating the average value obtained and the percentage of the number of students who met the minimum completion criteria (KKM) in the two classes that had been tested, as well as the observation sheet through the scientific learning approach carried out during the learning process. These results are explained in Table 6.

Table 6. Results of Post-test Scores for Experimental Class

No	Score Range	Frekuensi	Achievement (%)	Criteria
1	90-100	2	8	Very good
2	79-89	6	24	good
3	68-78	14	56	Enough
4	0-67	3	12	Not enough

Meanwhile, the results for grouping the post-test scores in the control class are presented in Table 7. Based on the results of the independent t-test in Table 9 above, a significance value of 0.012 <0.05 can be obtained, and this indicates that the hypothesis is not rejected; in other words, the competency test scores between the two classes are significantly different. This difference indicates that the use of this teaching material appears to improve students' high-level thinking skills, as described in Tables 6 and 7, as the experimental class obtained a higher average competency test score than the control class. The percentage of KKM score achievement in the experimental class can reach 88.0%, whereas in the control class it is only 65.4%, indicating that the developed teaching materials are effective for use in subsequent learning processes (Muhammad, 2018).

Table 7. Results of Grouping of Post-Test Scores for Control Class

No	Score Range	Frekuensi	Achievement (%)	Criteria
1	90-100	0	0	Very good
2	79-89	2	7,69	Good
3	68-78	15	57,69	Enough
4	0-67	9	34,62	Not enough

Thus, the importance of developing teaching materials for hydrocarbon chemistry lessons through this scientific approach. Because the existing teaching materials so far are considered to provide less contribution, especially in the development of high-level thinking skills of students (Allan et al., 2009). This view is that most teaching materials so far have simplified the content, material and scope of discussion too much, so that it can hinder the development of student thinking and is still considered low (Koseoglu, 2008), while Retnoningrum explained that the development of teaching materials cannot be focused on student competencies (Retnoningrum, 2016) and does not meet the targets of a curriculum (Kholilah, 2021). Therefore, the development of teaching materials is an important part of learning activities, according to the applicable curriculum, so that it can then contribute to the development of creativity and thinking skills of students (Bestiantono et al., 2020). In the above context, the development of teaching materials on hydrocarbons in chemistry subjects employs a scientific approach and is designed to meet the needs of students, particularly at SMAN 1 Paiton, Probolinggo Regency (Kurniawan et al., 2020).

Table 8. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
Mark	Equal variances assumed	.841	.364	2.619	49
	Equal variances not assumed			2.627	48.465

The development of hydrocarbon teaching materials for chemistry subjects is supported by various illustrations to enhance students' understanding. Therefore, the development of hydrocarbon teaching materials using a scientific approach can include several aspects, including observing, asking, exploring, reasoning and communicating, so that the teaching materials that are built can attract students' interest in learning and are considered suitable for application in educational institutions, especially for SMAN 1 Paiton Probolinggo Regency. The feasibility of the teaching materials is supported by their compliance with writing standards, including content, language, presentation and graphics (Ilmah et al., 2020). The above view, as can also be seen in the effectiveness test of teaching material development, through three indicators including; post-test results, percentage of student attendance who achieved the KKM score and analysis of the difference test results of the post-test, while the results of the post-test of the experimental class showed an average value of 75.68%, while in the control class it is 68.46%. In addition, the percentage of students in the experimental class who met the KKM was 88%, whereas the control class achieved only 65.4%.

Table 9. Independent Samples Test

		t-test for Equality of Means				
		Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Mark	Equal variances assumed	.012	7.21846	2.75612	1.67983	12.75709
	Equal variances not assumed	.012	7.21846	2.74815	1.69430	12.74262

In the above context, it can be concluded that there is a significant difference in learning outcomes across different teaching materials, thereby improving students' higher-order thinking skills. Furthermore, this effect is also influenced by the overall content of the teaching materials, with the student response rate after using hydrocarbon teaching materials categorised as very good and deemed suitable for application in chemistry learning. Meanwhile, effectiveness testing can be conducted during ongoing learning activities by providing students with understanding through a scientific approach in the experimental class, with results that were better compared to the control class (Rahayu & Suhaeb, 2018).

Thus, the overall results of the analysis can be explained that the level of success of the use of teaching materials based on the learning approach through 5M with the concept of the attractiveness of the teaching materials above can improve the quality of education, this is based on several advantages of hydrocarbon teaching materials, including: The teaching materials can significantly build and improve students' understanding of chemistry learning, in addition to the essence of the teaching materials above has gone through a feasibility test process carried out by validators from teachers, colleagues and students. The development of the teaching materials above is presented in a contextual, scientific manner, thereby providing direct learning experiences and developing students' high-level thinking skills. The teaching materials can foster active and effective learning, as evidenced by the percentage of students achieving the KKM value in chemistry lessons.

Conclusion

Based on the discussion above, this research can be concluded as follows: producing teaching materials in a scientific manner enables effective and efficient learning activities, particularly in chemistry. The development of chemistry teaching materials can be implemented effectively when they meet eligibility standards as verified by verification tests, thereby improving student learning outcomes. This is evidenced by a KKM value above the class average (88%) in the experimental class, with an average post-test value of 75.68, which is higher than that of the control class (65.4%), with an average post-test value of 68.46. The teaching materials created can significantly improve students' higher-order thinking skills. On the other hand, digital teaching materials still require two-way communication between students and teachers, enabling well-controlled learning activities through the validation process of individual and field trials. Thus, the development of teaching materials is not limited to hydrocarbons but can be extended to other materials to increase students' interest in learning chemistry.

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