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Epistemic Knowledge Assessment Instrument on Energy Crisis Material for Junior High School Students

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ABSTRAK

Pengetahuan epistemik adalah salah satu pengetahuan yang diukur pada literasi sains. Instrumen penilaian belum dikembangkan secara khusus untuk mengukur pengetahuan epistemik. Penelitian ini bertujuan untuk menghasilkan instrumen penilaian yang dapat digunakan untuk mengukur tingkat pengetahuan epistemik siswa SMP. Instrumen penilaian ini dikembangkan dalam bentuk esai. Tahapan pengembangan instrumen ini adalah mengembangkan indikator pengetahuan epistemik, menyusun pertanyaan tiap indikator, menguji validitas dan reliabilitas instrumen. Sebanyak 60 siswa SMP di Tebing Tinggi menjadi sampel penelitian. Instrumen penilaian ini terdiri dari empat aspek pengetahuan epistemis, model, data dan bukti dalam pernyataan ilmiah, sifat penalaran ilmiah, dan hakikat sains yang umum dan kolaboratif. 1 dari 15 item soal valid dengan kriteria tinggi, 12 item soal valid dengan kriteria sedang, dan 2 lainnya valid dengan kriteria rendah. Uji reliabilitas menggunakan KR-20 dan hasilnya instrumen penilaian ini reliabel dengan kriteria sangat tinggi. Hasil analisis menunjukkan bahwa pengembangan instrumen penilaian pengetahuan pada materi krisis energi dapat digunakan karena valid dan reliabel.

ABSTRACT

Epistemic knowledge is one of the knowledge measured in scientific literacy. Assessment instruments have not been developed specifically to measure epistemic knowledge. This study aims to produce an assessment instrument that can be used to measure the level of epistemic knowledge of junior high school students. This assessment instrument was developed in the form of an essay. The stages of developing this instrument are developing indicators of epistemic knowledge, compiling questions for each indicator, and testing the validity and reliability of the instrument. A total of 60 junior high school students in Tebing Tinggi were the research samples. This assessment instrument consists of four aspects of epistemic knowledge, models, data and evidence in scientific statements, the nature of scientific reasoning, and the general and collaborative nature of science. 1 of 15 test items is valid with high criteria, 12 test items are valid with medium criteria, and 2 others are valid with low criteria. The reliability test used KR-20 and the results showed that this assessment instrument was reliable with very high criteria. The analysis results showed that the development of a knowledge assessment instrument on the energy crisis material can be used because it is valid and reliable.

1. INTRODUCTION

Students plays a strategic role in forming science-literate students. Students are expected to understand the basic concepts of science and apply this knowledge in daily decision-making (Yuliati, 2017). One of the challenges in science learning is ensuring that students understand conceptual and epistemic knowledge. Epistemic knowledge refers to the understanding of how scientific knowledge is developed, validated, and used (Rahayu, 2017). Epistemic knowledge is needed so that students are able to filter and evaluate diverse scientific information, understand the dynamics of theories and evidence, and apply this knowledge critically in their lives (Feinstein & Baram-Tsabari, 2024; Greene et al., 2016; Lee et al., 2021).

In the Indonesian education curriculum, science learning at junior high school level is designed to create a strong foundation in understanding scientific concepts in depth, one of which is the concept of the energy crisis. This concept is very relevant to daily life, such as energy use, resource conservation, and its impact on environmental sustainability (Shah et al., 2021). The energy crisis material provides a great opportunity to explore epistemic aspects. The concept of energy is abstract (Subiki et al., 2022), and be found in various phenomena in everyday life, such as human body metabolism, energy transfer in ecosystems, and the use of energy in human activities.

To understand the energy crisis material, students need to integrate content knowledge with epistemic knowledge. However, measuring the extent to which students understand energy concepts epistemically is still difficult (Asnawi et al., 2020; Billingsley & Heyes, 2023). In general, assessments only focus on basic cognitive abilities and conceptual knowledge, such as remembering and understanding facts, which are not enough to describe students' epistemic abilities. To measure the dimensions of epistemic knowledge, an assessment instrument is needed that is specifically developed with several aspects adapted from the PISA 2025 framework (OECD, 2023). Epistemic knowledge aspects can be seen in Table 1.

Table 1. Epistemic knowledge aspects

Aspects	Indicator
Models	How the understanding of the material world is constructed using physical, conceptual, system and mathematical models in science
	The distinction between a model and reality
	How models enable predictions and explanations
	How the limitations of models constrain their use
Data and evidence in scientific claims	How scientific claims are supported by data, methods, reasoning and evaluation in science
	How scientific evidence is generated e.g. the nature of the practices undertaken by scientists
	How measurement error affects the degree of confidence in scientific knowledge
The nature of scientific reasoning	Some of the different forms of empirical enquiry, field work and its role, controlled experiments, pattern seeking
	The types of reasoning (deduction, abduction, induction, probabilistic thinking) used in establishing knowledge and their goal (to test explanatory hypotheses, or identify patterns and entities)
	The ethical dilemmas raised in scientific practice
	The role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues and its limits
The collaborative and communal nature of the sciences	How specific scientific research is funded and supported e.g. government, private and the mechanisms for deciding
	The importance of consensus in warranting belief
	How peer review helps to establish confidence in scientific claims and is dependent on a scientific community
	Key scientific practices undertaken by scientists to produce shared knowledge, their role and their collaborative nature
	The limits to certainty and confidence in scientific findings, how it is expressed, the evolution of certainty and the role of consensus
	How scientific findings are communicated within the community and to the public

This instrument represents all four aspects, although not all indicators. This instrument must capture the complexity of students' thinking and provide a comprehensive picture of the extent to which they understand where the knowledge was obtained and can apply scientific attitudes to the knowledge discovered.

Epistemic knowledge assessment instruments can help change the learning paradigm from being outcome-oriented to being process-oriented (Lee et al., 2021). Thus, this instrument is no longer only seen as a tool for measuring learning outcomes, but as an integral part of the learning process itself. This is also in line with 21st century learning approaches which emphasize the importance of developing critical thinking skills (Arafah & Hakim, 2022; Muchtar, 2010; Shaffer et al., 2009). Understanding epistemic knowledge helps students analyze, evaluate, and differentiate knowledge claims (Putri, 2020). Students who have good epistemic knowledge are more critical in questioning sources of information, understanding information bias, and assessing the validity of arguments.

In scientific literacy, there has not been much development of epistemic knowledge assessment instruments. Generally, researchers develop scientific literacy assessment instruments without separating aspects of knowledge, namely content, procedural, and epistemic knowledge. Scientific literacy assessment instruments have been developed by Wahyunisah, Martinah, Putri, Novanti, Astuti, on the respiratory system, environmental pollution, the diversity of living things, the pressure of substances and its application, and the excretory system (Astuti et al., 2012; Khoirun et al., 2018; Martinah et al., 2022; Putri, 2020; Wahyunisah & Susilawati, 2023). The epistemic knowledge assessment instrument on the energy crisis material has not been specifically developed. This material supports the content knowledge assessed in PISA 2025 (OECD, 2023). Energy crisis material is studied by junior high school students in grade IX in the Merdeka curriculum (Mubarak, 2022). In other words, the issue of the energy crisis is important to understand and it is necessary to develop this instrument to measure students' epistemic knowledge. A good assessment instrument is a valid and reliable instrument (Heale & Twycross, 2015; Rochim et al., 2024). Valid instruments produce legally admissible assessment outcomes, while reliable instruments ensure consistent results suitable for repeated use (Fairuz, 2021). This instrument is expected to help evaluate epistemic knowledge and increase students' scientific literacy. Thus, this study aims to develop a valid and reliable epistemic knowledge assessment instrument on the energy crisis material.

2. METHOD

This research uses research and development methods adapted from (Fairuz, 2021). The stages of developing an epistemic knowledge assessment instrument are developing epistemic knowledge indicators, compiling questions for each indicator, and testing the validity and reliability of the instrument. Figure 1 shows the stages of the research method and development of the assessment instrument.

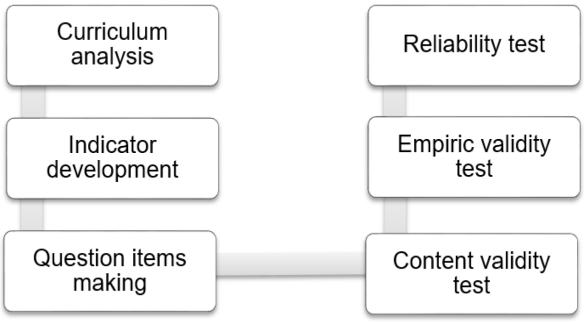

Figure 1. Stages of research methods of assessment instruments

Indicators for each aspect of epistemic knowledge were developed from the PISA 2025 science framework. Each question was arranged in the form of an essay test based on the cognitive level of junior high school students and the energy crisis material. The research instrument was then validated in two stages, namely content validation by three experts and empirical validation with limited instrument testing. After the instrument was declared valid, the questions were tested for reliability. The sample for the reliability test was 60 junior high school students in Tebing Tinggi. Content validity data were analyzed by looking at the accuracy of the instrument material with indicators, objectives, aspects of capability, language validity, and suitability of images. The data of empirical validity were analyzed using the Pearson Product-Moment formula which correlates the score of a particular item with the total score. Data to measure reliability were analyzed using the Kuder-Richardson (KR20) approach.

3. RESULT AND DISCUSSION

3.1. Result

The instrument for assessing epistemic knowledge was developed in essay form. Epistemic knowledge consists of four aspects, namely models, data and evidence in scientific claims, the nature of scientific reasoning, and the collaborative and communal nature of the sciences (OECD, 2023). The question indicators were developed from the four aspects. After the indicators were developed, they were arranged into 15 question items, and the instrument was validated by three experts as part of content validation.

Expert evaluation was conducted to enhance the clarity and precision of items that may be prone to misinterpretation or ambiguity, thereby ensuring their alignment with the designated indicators of epistemic knowledge. The experts concluded that the formulated questions were valid and appropriate for assessing the science process skills of junior high school students, and they proposed minor revisions to further improve their effectiveness. Furthermore, the questions were tried out limited to 60 students in Tebing Tinggi to determine the validity value, the results can be seen in Table 2.

Table 2. The empirical validity of each question

Question number	Validity r_{tab} = 0,2542	
	Value	**Criteria**
1	0,3996	Low
2	0,4010	Medium
3	0,5155	Medium
4	0,5155	Medium
5	0,3627	Low
6	0,6230	High
7	0,5392	Medium
8	0,5500	Medium
9	0,5392	Medium
10	0,5958	Medium
11	0,4334	Medium
12	0,4582	Medium
13	0,4611	Medium
14	0,4611	Medium
15	0,5146	Medium

Based on the results of empirical validity in Table 2, 15 questions to assess epistemic knowledge are declared valid with 2 questions with low criteria, 12 questions with medium criteria, and 1 question with high criteria. The reliability test was conducted on 60 junior high school students. The results of the reliability test analysis can be seen in Table 2, where the KR-20 coefficient of the epistemic knowledge assessment instrument is 0.8747, which means that this instrument is reliable with very high criteria. Thus, the epistemic knowledge assessment instrument with the energy crisis material in junior high schools is valid and reliable.

Table 3. Reliability test

Reliability			
r_{count}	r_{table}	Inference	Criteria
0,8747	0,2542	Reliable	Very High

3.2. Discussion

Epistemic knowledge is one of the knowledge needed in scientific literacy. Epistemic knowledge refers to the understanding of how to construct and define essential aspects in science knowledge, as well as its role in validating the science product (Zetterqvist & Bach, 2023). Thus, epistemic knowledge provides a rationale for the procedures and practices carried out by scientists, an understanding of the structures and characteristics that guide scientific investigations, and a foundation for believing the claims made by science about nature. Epistemic knowledge is relevant to conceptual understanding and argumentation in cognitive domains, so it needs to be developed in learning (Hasnunidah et al., 2022).

Argumentation serves as a pivotal tool in science education for enhancing epistemic knowledge. It involves the construction and evaluation of claims supported by evidence, thereby facilitating the development of scientific reasoning and critical thinking skills. Engaging students in argumentation activities allows them to make explicit epistemic decisions, thereby deepening their understanding of scientific practices. Argumentation provides opportunities for students to articulate their reasoning, evaluate evidence, and engage in discussions that promote a deeper understanding of scientific concepts (Erduran & Jimenez-Aleixandre, 2007; Septaria, 2019).

Epistemic knowledge is intricately linked to conceptual understanding in science education. It enables students to grasp the nature of scientific knowledge, the processes through which it is developed, and the criteria for its justification. This understanding is crucial for interpreting scientific concepts accurately and applying them effectively in various contexts. By developing epistemic knowledge, students are better equipped to engage in scientific inquiry, evaluate evidence, and construct well-founded arguments.

A study by (Jin & Kim, 2021) conducted a qualitative case study examining elementary students' epistemic understandings in scientific argumentation. The study found that students' epistemic understandings influenced their argumentative practices, affecting the ways they engaged in argumentative dialogues. The research highlighted the potential for students to refine their epistemic understandings through social interactions with peers, adapting their knowledge in new contexts.

The topic of the energy crisis provides a relevant and engaging context for developing epistemic knowledge in science education. It intersects with various real-world issues, including environmental sustainability, technological innovation, and societal challenges (Adewnmi et al., 2023). By exploring the energy crisis, students can apply scientific concepts to analyze complex problems, evaluate evidence, and develop informed perspectives. This process fosters critical thinking and promotes a deeper understanding of the interconnectedness of scientific knowledge and societal issues. In the context of junior high school education, it is essential to introduce students to the foundational concepts related to the energy crisis. This approach enables students to apply their understanding in meaningful ways, enhancing the relevance and impact of their learning experiences. By engaging with real-world issues, students can develop the skills necessary to navigate complex scientific and societal challenges. The application of science and technology, in the personal, local, national, and global scopes used as a context for assessment items including: Health and disease, Natural resources, Environmental quality (including environmental impacts and climate change), Hazards, The vanguard of science and technology (including current progress and challenges) where the energy crisis plays a role in it (OECD, 2023). In the understanding of junior high school students, they must understand the foundation of the concept in the energy crisis material so that they can apply it in life in depth and become meaningful learning.

The assessment instrument was developed by adapting the PISA instrument with six stages of development. After the curriculum was analyzed, the material was determined according to the curriculum. The energy crisis material is studied in junior high school and its depth and breadth are adjusted to its cognitive level. This material is also adjusted to the personal, local, national, and global scopes. Then, indicators are developed in each aspect of epistemic knowledge. After the indicators are compiled, questions are made as an instrument for assessing epistemic knowledge. There are 15 questions made and their content is validated by three experts. The questions were revised according to the direction of the experts, starting from grammar, appropriateness of content and images, to clarity of concepts, so as not to cause misconceptions and ambiguities. The next stage is the empirical validity test and reliability test. The validity and reliability tests were given to 60 grade IX junior high school students in Tebing Tinggi randomly. 13% of the epistemic knowledge assessment instruments were valid with low criteria, 80% were valid with medium criteria, and 7% were valid with high criteria. This assessment instrument is reliable with very high criteria, meaning it can be trusted and used with the same results. The following is a summary of questions in each aspect of epistemic knowledge that have been validated and are reliable.

1. *Bacalah artikel di bawah!*

   KBRN, Jakarta: Kemenkes RI membeberkan, dampak polusi udara yang terjadi di Indonesia meningkatkan jumlah kasus ISPA (Infeksi Saluran Pernapasan Akut). Dari data tahun 2021-2023, ISPA terus meningkat dan sudah menembus 200 ribu kasus. "Data-data menemukan, tahun 2021 kurang dari 3000 kasus ISPA dilaporkan, tahun 2022 meningkat 50.000-70.000 kasus. Sedangkan 2023 kita mendapatkan angka di akhir tahun atau awal Januari mencapai 200.000 ISPA," kata Kepala Biro Komunikasi Dan Pelayanan Publik Kemenkes Siti Nadia Tarmizi, saat berbincang dengan PRO3 RRI, Rabu (30/8/2023). Kemudian, Nadia menekankan, kondisi udara yang tidak sehat sangat mempengaruhi terjadinya ISPA di Indonesia. Pemerintah diharapkan, segera mengentas permasalahan udata di Tanah Air. (https://www.rri.co.id/nasional/339812/kemenkes-catat-pengidap-ispa-meningkat-akibat-polusi-udara)

   Berdasarkan artikel di atas, bagaimana cara virus menular pada kondisi udara yang tidak sehat itu?
2. *Perhatikan cuplikan artikel berikut.*

   Sudah tidak bisa dipungkiri lagi bahwa penggunaan air yang berlebihan bisa membuat air bersih semakin berkurang. Sayangnya, masih ada saja masyarakat yang tidak peduli dengan hal ini. Buktinya, ada yang membiarkan kran air tetap terbuka lebar pada saat tidak digunakan. Ada pula yang gemar berendam di bathtub yang notabenenya memerlukan air dalam jumlah cukup banyak. Ada yang tetap membuka kran air ketika sedang menggosok gigi, membuka kran air lebar-lebar ketika mengambil wudhu padahal ketika melakukan gerakan-gerakan wudhu ada jeda yang membuat air bersih jadi terbuang banyak.

   Manakah dari pernyataan berikut yang dapat berdasarkan bukti ilmiah dan manakah yang berdasarkan pengetahuan lain? Berikan alasan!
   1) *Sekitar 2 miliar orang menggunakan sumber air minum yang terkontaminasi tinja, yang menyebabkan lebih dari 485.000 kematian akibat diare setiap tahun.*
   2) *Penggunaan air secara berlebihan dapat menyebabkan besarnya pembayaran listrik.*
   3) *Lebih dari 25% populasi global tinggal di negara yang mengalami tekanan air (water stress).*
   4) *Menurut Intergovernmental Panel on Climate Change (IPCC), perubahan iklim akan memperburuk kelangkaan air di banyak wilayah, terutama di daerah kering.*
   5) *Masyarakat tidak peduli dengan ketersediaan air bersih mungkin karena terbiasa dengan air yang melimpah.*
3. *Teknologi pembangkit listrik tenaga surya dibuat dengan meniru prinsip daun yang memanfaatkan energi matahari untuk menghasilkan energi kimia, sehingga dapat menjadi alternatif sumber energi yang sangat*

bermanfaat. Jelaskan bagaimana panel surya mengubah energi matahari menjadi energi listrik hingga prosesnya seperti fotosintesis!

4. *Pembuangan sampah yang tidak tepat dapat menyebabkan berbagai masalah lingkungan dan kesehatan. Sampah yang dibuang sembarangan dapat mencemari tanah, air, dan udara. Selain itu, sampah yang menumpuk dapat menjadi sarang penyakit dan menarik hewan pembawa penyakit seperti tikus dan nyamuk. Untuk menyebarkan cara buang sampah yang benar kepada publik atau komunitas, diperlukan strategi edukasi yang efektif. Bagaimana strategi edukasi yang efektif tersebut?*

Question number 1 is a question that represents the model aspect with an indicator of understanding the transmission of ISPA using a conceptual model of viruses. With the data provided as a model, students are expected to be able to understand viral transmission in ISPA. Question number 2 is a question that represents the data and evidence aspect in scientific statements with an indicator of analyzing scientific evidence supported by data, methods, reasoning, and evaluation in the issue of clean water availability. With the statements in the article presented, students are expected to be able to analyze statements related to the availability of clean water as scientific evidence or just knowledge. Question number 3 is a question that represents the nature of scientific reasoning with an indicator of explaining the working principles of solar panels together with the process of photosynthesis. Students are expected to be able to use scientific knowledge about photosynthesis in explaining solar panel technology. Question number 4 is the general and collaborative nature of science with an indicator of communicating the correct and proper way to dispose of waste. By presenting the problem of waste, students are expected to be able to communicate how to dispose of waste correctly based on the nature of science. These questions represent all aspects of epistemic knowledge that are expected to measure how good students' epistemic knowledge is on the energy crisis material.

4. CONCLUSION AND RECOMMENDATION

This study successfully developed a valid and reliable instrument to assess junior high school students' epistemic knowledge on the topic of energy crisis. The instrument reflects four essential aspects of epistemic understanding and is aligned with international science assessment standards. Its use in classroom settings can enhance diagnostic assessment and support epistemic-oriented teaching. The findings contribute to the growing need for instruments that go beyond content mastery and evaluate how students understand the nature of science.

It is recommended that science teachers utilize this instrument as part of formative assessment to promote reflective thinking and scientific reasoning. Future studies may adapt this instrument for other science topics or modify it into multiple-choice format for broader applicability. Furthermore, longitudinal studies could investigate the impact of epistemic assessment on students' scientific literacy growth over time.

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