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ASSESSING ENGINEERING EPISTEMOLOGY: A SYSTEMATIC LITERATURE REVIEW OF INSTRUMENTS

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ABSTRACT

This research paper presents an overview and evaluation of existing instruments utilized to assess epistemological beliefs, beliefs people hold regarding the nature of knowledge and knowing, including how knowledge is constructed and its certainty or tentativeness, within the context of engineering education.

Assessment of epistemological beliefs in engineering education is crucial for understanding students' perspectives on knowledge and learning. To successfully carry out such an assessment, we need validated reliable psychometric tools. A literature review on the subject revealed a lack of evidence on the state of knowledge on epistemology in engineering education.

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To address that gap, we conducted a systematic literature review spanning from 1997 to 2023 across representative databases and journals in the field and guided by the question, "What existing instruments are designed to measure or characterize epistemological beliefs in engineering?"

The search revealed two instruments, and upon further examination, we concluded that none of the quantitative instruments already available are based on a conceptually coherent and empirically robust model of epistemic development in engineering, and hence can’t be used to produce reliable measures.

The engineering education research community need to dedicate efforts towards designing and validating an engineering-specific epistemological tool. The creation and validation of such an instrument is a step towards understanding epistemological beliefs among engineering students, which in turn is crucial for effective instructional design and curriculum development. We posit that such development offers a nuanced supplement to conventional grading-centric assessments.

1 INTRODUCTION

1.1 Background

There are four popular types of beliefs typically studied in engineering education: epistemic, self-efficacy, mindset, and goal-orientation beliefs (Kramer et al., 2024). This study will focus on epistemic beliefs, which are the beliefs that people have about the nature of knowledge and knowing, such as what counts as knowledge, how knowledge is constructed, and how certain or tentative knowledge is (Hetherington, 2012).

Assessing epistemological beliefs in engineering education is crucial for understanding students' perspectives on knowledge and learning. They also have implications for various aspects of cognition, motivation, and achievement (Chai et al., 2006; Muis et al., 2006). Carberry (2010) and Frye et al. (2012) both found that engineering students often hold simplistic and certain views of knowledge, which can impact their learning and comprehension of engineering concepts. Ghazali et al. (2021) further emphasizes the importance of understanding and shaping students' epistemological beliefs, suggesting that educators play a key role in this process. An educator’s own epistemological beliefs influence teaching and learning (Bendixen & Rule, 2004; Green & Hood, 2013; Montfort et al., 2014) which underline all instructional design aspects including teaching strategies, learning objectives, and assessment techniques. Educators need to know what the students know to in turn design better educational experiences (Turns et al., 2005), further proving the practical implications of measuring and characterizing epistemic beliefs (Yildirim et al., 2010). These studies collectively highlight the significance of assessing and addressing epistemological beliefs in engineering education, which in turn responds to recent calls in the field for explicitly defining and measuring beliefs as a construct (Kramer et al., 2024), and addressing the lack of philosophical engagement with epistemology in the context of engineering disciplines (Boon & Baalen, 2018).

1.2 Literature Review

Looking at all existing instruments to measure epistemic beliefs, we grouped existing instruments into three groups: 1- Domain-general: typically have been created by psychologists to be widely applied to various contexts or majors of study e.g. Epistemic Beliefs Inventory. 2-domain-specific-non-engineering: Instruments that are designed for a specific field or context outside of engineering, and at times borrowed and applied to engineering. e.g. MED NORD a tool designed for medical students' conceptions of knowledge (Lonka et al., 2008) 3- Domain-specific engineering: Instruments that are designed for engineering and have been validated to be used with engineering students. This paper and the following analysis focused only on instruments falling in the third category mentioned above, engineering-specific instruments.

Research in the field of epistemological beliefs among university students has revealed notable disparities in how individuals perceive knowledge across different academic disciplines. Hofer (2000) discovered such disparities between first-year college students studying science and psychology. Similarly (Palmer & Marra, 2004) found similar differences in epistemological perspectives of science and engineering university students varying across the disciplinary areas of the sciences and the humanities. Faber & Benson (2017) further emphasized that epistemic cognition in engineering may diverge from other fields due to the distinctive nature of engineering knowledge and problem-solving demands. A component of studying knowledge – epistemology- is looking at individuals' justification of knowledge claims. DeBacker et al. (2008) argue that epistemic beliefs are domain-specific, as individuals may employ varying standards and justifications across different fields.

Hence, the study of epistemic beliefs can't be separated from the standards and practices in a given context, because those beliefs are contextualized within a context and hence ruled by disciplinary boundaries (Pintrich, 2002; Yu & Strobel, 2011) which raised criticism against domain-general instruments for their inability to capture the nuances of disciplinary differences (Hofer, 2000). These arguments collectively point towards the discipline-dependent nature of epistemic beliefs and consequently should be the instruments measuring them, therefore the focus of our paper here is on domain-specific engineering instruments.

2 METHODOLOGY

2.1 Method

Systematic Literature Review (SLR) is a research methodology aimed at critically appraising patterns or gaps in a given topic through synthesizing prior work on a given subject within a defined time frame to better identify new directions of research (Petticrew & Roberts, 2006). SLR can be done for different primary goals including tracing historical development, describing the state of knowledge or practice, or evaluating or developing theory (Borrego et al., 2014). This review will focus on the second purpose which is to identify existing research instruments designed to characterize epistemological beliefs. The particular focus of the search was on seminal research that documents the creation of such instruments, as well as research done on the validation and use of those instruments across contexts. The search is guided by the question: What are the existing instruments designed to measure/characterize epistemological beliefs in engineering?

The selection of the search terms was informed by the team's expertise as well as referencing the engineering education research taxonomy (Finelli & Borrego, 2015).

The resulting search combination is Epistem* AND Engineer* AND (Beliefs OR persp* OR cogniti* OR thinking) AND (instrument OR test OR questionnaire OR survey).

To define the inclusion and exclusion criteria of the papers found, we considered the language of publication, type of content (excluded editorials), population targeted by studies (exclude studies of children, K-12), discipline (as explained by the typology) and bounded the search with a year range.

Following the official language of our institution, our intended study will be conducted in English. Therefore the instrument has to be originally written in English, or a version translated to English is validated [when an instrument is translated or adapted from a different language, new evidence of validity should be conducted (American Educational Research Association et al., 2014)].

Data collected included studies from 1997 to 2023. The start of the date range was decided based on the publication of Hofer and Pintrich's (1997) meta-analysis of students' epistemological belief research that critically examined different research projects' use of definitions and theoretical framework related to the subject and presented theoretical and methodological issues in those studies.

The number and categories of databases to use for the SLR is a vital step in ensuring accurate search results and reducing selection bias as much as possible. While there is an agreement on the importance of defining and restricting the number and type of databases to include in a search (Mengist et al., 2020) the exactness of the criteria is less agreed upon. To decide on that step, we referenced multiple sources (Borrego et al., 2014; Bramer et al., 2017) and decided to focus on the databases Web of Science and Scopus to guarantee efficient coverage.

2.2 Analysis

Studies were screened following the pre-defined criteria, as reported in Table 1. Initial screening was performed by studying the title of the publication and categorizing it into one of three buckets: To include (Yes, No, or Maybe). Publications that didn't develop an instrument, or use a domain-general instrument to address engineering university-level education were labelled "No" and excluded. The publications where it wasn't clear from the title whether they developed or applied an instrument were labelled "maybe". The second round of the search tackled the group labelled as "maybe" by reading the abstract and deciding whether or not to include them. The last round of the search retrieved the full papers that got labelled as "Yes". If any of those papers didn't discuss an instrument, they were further excluded. This resulted in two instruments discussed across six papers as shown in Table 2.

Table 1: SLR search results and filtration

Database searched	Example journals and conference proceedings included in the database search	No. of results yielded in the initial search	Results based on initial categorization	Results based on intermediate categorization	Final results
Web of Science	International Journal of Engineering	112	Yes: 4 No: 86	Yes: 17 No: 95	Yes: 6 No: 106

	Education; Journal of Engineering Education; Frontiers in Education		Maybe: 22		
Scopus	European Journal of Engineering Education; American Society of Engineering Education	134 (55 overlapped with WoS results, 79 new papers)	Yes: 0 No: 63 Maybe: 16	Yes: 0 No: 16	No new papers added beyond the 5 above

Table 2: Finalized list of papers included following the search criteria

Instrument	Paper	Paper purpose
The Epistemological Beliefs Assessment for Engineering (EBAE)	1- A Pilot Validation Study of the Epistemological Beliefs Assessment for Engineering (EBAE): First-Year Engineering Student Beliefs (Carberry et al., 2010)	Instrument developing
	2- Assessing Engineering Service Students' Characteristics (Carberry, 2010)	Instrument application
The Engineering Related Beliefs Questionnaire (ERBQ)	3- A first step in the instrument development of engineering-related beliefs questionnaire (Yu & Strobel, 2012)	Instrument developing; Analysis of EBAE
	4- Exploring engineering students' epistemic beliefs and motivation: a case of a South African university (Makhathini et al., 2020)	Instrument application
	5- Measuring engineering epistemic beliefs in undergraduate engineering students (Faber et al., 2016)	Instrument application
	6- Engineering Students' Epistemic Cognition in the Context of Problem Solving (Faber & Benson, 2017)	Instrument application

3 RESULTS

3.1 Summary of Papers

3.1.1 A Pilot Validation Study of the Epistemological Beliefs Assessment for Engineering (EBAE): First-Year Engineering Student Beliefs

EBAE (Carberry et al., 2010) is a quantitative instrument to assess engineering students' epistemological beliefs. It is based on Hofer and Pintrich's (1997) dimensions of epistemological beliefs and includes items concerning the nature of engineering knowledge (certainty of knowledge, simplicity of knowledge) and the nature of engineering knowing (source of knowing, and justification of knowledge). It was piloted with 43 first-year engineering students in the US context resulting in thirteen validated items in four constructs.

3.1.2 Assessing Engineering Service Students' Characteristics

This paper studies students' epistemological development in the context of service learning. To understand how to integrate service opportunities into engineering education, the author set out to understand why students are drawn to these experiences and the reasons behind their inclination towards service. The paper has a significant focus on assessing students’ engineering epistemological beliefs, and hence its inclusion in our selected papers. Using EBAE as a data collection tool, preliminary results suggested students exhibiting sophisticated engineering epistemological beliefs.

3.1.3 A first step in the instrument development of engineering-related beliefs questionnaire

The paper presents a framework for understanding engineering-related beliefs, which are crucial for students’ learning and problem-solving in engineering. They aim to develop a reliable and valid Engineering-related Beliefs Questionnaire, focusing on engineering knowledge, skills, attitudes, identity, and values. The paper contributes to the field by attempting to measure and support the change in students’ beliefs, hence its inclusion in our final list of papers.

3.1.4 Exploring engineering students’ epistemic beliefs and motivation: a case of a South African university

The paper investigates the epistemic beliefs and motivations of chemical engineering students from low-income communities in South Africa. The study explores how students perceive knowledge construction, using the Engineering Related Beliefs Questionnaire (ERBQ). It reveals that many students view engineering knowledge as unchallengeable and learning as a passive process.

3.1.5 Measuring engineering epistemic beliefs in undergraduate engineering students

The paper investigates undergraduate bioengineering students’ epistemic beliefs. It utilizes ERBQ and open-ended items to validate the instrument, hence we included the paper in the final list. The researchers’ analysis revealed inconsistencies in students’ interpretations of survey items, suggesting a need for clearer language to accurately capture their epistemic beliefs.

3.1.6 Engineering Students' Epistemic Cognition in the Context of Problem Solving

The study explores the connection between engineering students’ epistemic cognition and their motivation when solving open-ended problems. Utilizing a mixed methods approach, partially based on ERBQ, the research identifies clusters of students based on their beliefs about the source and certainty of engineering knowledge, as well as their openness to new ideas. Findings suggest that students’ approaches to problem-solving are influenced by their epistemic beliefs and motivations.

3.2 Analysis of Papers

3.2.1 The Epistemological Beliefs Assessment for Engineering (EBAE)

As reported by the authors of the instrument, the sample size they used (N = 43) is smaller than the minimum recommended for performing a factor analysis, which affects the validity of the results they reported. Also, no internal consistency measures (Cronbach alpha) were reported. The authors also ran into the problem of low participation rate (27%) which raises concerns about the generalizability of the findings to all first-year engineering students.

In terms of other works that tried using this instrument, (Carberry, 2010) didn't validate the instrument items using factor analysis or test for reliability as the study reported in the publication was a work-in-progress. (Yu & Strobel, 2011) analysis of the instrument found that only two items were directly related to engineering epistemology, while the rest addressed learning or general epistemological beliefs without adopting domain-specific constructs. (Faber et al., 2016) reported a similar critique that although the instrument is intended for engineering-specific epistemology, it is not specific enough to engineering.

Overall, the limitations reported for the EBAE suggest that further refining of the items to accurately measure engineering-specific epistemological beliefs is needed, as well as validating the instrument with a larger and more diverse sample of responders.

3.3 The Engineering Related Beliefs Questionnaire (ERBQ)

To establish this instrument, the researchers (Yu & Strobel, 2011) first developed a conceptual framework that acknowledges the connection between epistemological beliefs, epistemic beliefs, and ontological beliefs. Following that framework, as well as Hofer and Pintrich's (1997) framework (similar to EBAE) the researchers collected several engineering-related beliefs items from existing studies that address each of the three aforementioned constructs, and after refinement, they presented a total of 22 items.

Although content validity testing was performed by the research team where they discussed the instrument in focus groups, they acknowledged that further testing of the instrument with engineering students is needed to produce the final version of the instrument. Their paper introduces a version of what the instrument could look like, but does not pilot test it. According to our search, this pilot was never performed by the research team or by other researchers.

Similar to the lack of addressing engineering-specific domain constructs reported for EBAE, Faber & Benson (2017) reported that ERBQ only includes two items directly related to engineering epistemology. Also, in their attempt to use the instrument they faced low internal consistency for the sub-scale of simplicity and knowledge. Faber et al.(2016) used ERBQ along with open-ended items to study how the students interpreted the items. Their analysis revealed inconsistencies between how the items are worded and the student's understanding of the items, which goes to show the importance of including some qualitative measures along with the numerical instrument.

Some researchers tried to implement that suggestion (Makhathini et al., 2020) by augmenting the items on the ERBQ with open-ended responses to invite the students to engage more deeply with the items on the instrument, and those responses were used for further validation. Their results discarded four of the original twelve items under the source of engineering knowledge construct due to claimed low-reliability factors. Similarly, they also discarded two of the original seven items under the certainty of knowledge construct, leaving 16 out of the original 22 items.

Overall, ERBQ needs iterative refinement of its items, as well as further testing, especially with engineering student populations to ensure the development of a robust and reliable instrument.

4 SUMMARY AND FUTURE WORK

In summary, the EBAE, as it stands, is compromised by several methodological limitations, including a small sample size (N = 43) for factor analysis, a lack of internal consistency measures, and a low participation rate (27%). These factors undermine the validity and generalizability of its findings. Additionally, critiques from subsequent studies (Carberry, 2010; Yu & Strobel, 2011; Faber et al., 2016) suggest that the EBAE fails to adequately capture engineering-specific epistemological beliefs, instead addressing more general epistemological constructs. To address these concerns, there is a clear need for refining the EBAE items to better reflect the unique aspects of engineering epistemology and for conducting rigorous validation studies with larger and more representative samples.

Similarly, the ERBQ also faces significant challenges. The absence of pilot testing and the reported low internal consistency of some sub-scales (Faber & Benson, 2017) cast doubt on its reliability. Furthermore, the findings from Faber et al. (2016) highlight the necessity of incorporating qualitative measures to complement quantitative data. Efforts by Makhathini et al. (2020) to augment the ERBQ with open-ended responses represent a promising step towards enhancing the instrument's validity. However, their results also led to the elimination of several items due to low reliability, underscoring the need for iterative refinement.

Overall, we were surprised by the small number of engineering epistemology-specific instruments found. In contrast to the science field where various quantitative instruments have been developed and utilized to measure epistemological beliefs about the nature of science e.g. the Nature of Scientific Knowledge Scale (NSKS), engineering lacks a contrasting domain-specific instrument dedicated to engineering knowledge.

Given the importance of domain-specific instruments (Faber & Benson, 2017; Hofer, 2000; Palmer & Marra, 2004), the engineering education research community needs to dedicate efforts towards designing and validating an engineering-specific epistemological tool. Such a tool would serve to guide, enable, and constrain the analysis and articulation of how knowledge is produced within the engineering field (Boon & Baalen, 2018). Which in turn enhances students' learning, motivation, and achievement (Chai et al., 2006; Muis et al., 2006), and teacher education (Bendixen & Rule, 2004; Green & Hood, 2013; Montfort et al., 2014) ultimately enabling educators to design better learning experiences for students (Tan et al., 2019; Turns et al., 2005).

Future work will expand the analysis by comparing the engineering-specific instruments presented here with some of the domain-general instruments like the

Epistemic Belief Inventory. In accordance with (Muis et al., 2006) epistemic beliefs are both domain-general and domain-specific, and such comparison will enable us to test this argument and consequently design an instrument that potentially provides a balance between domain-general and domain-specific beliefs. We believe this will be particularly useful in characterizing epistemic beliefs at interdisciplinary boundaries when more fluid dimensions are needed to account for the moving lines of context and domain in interdisciplinary work.

REFERENCES

American Educational Research Association, American Psychological Association, & National Council on Measurement in Education. (2014). *Standards for educational and psychological testing*.

Bendixen, L. D., & Rule, D. C. (2004). An Integrative Approach to Personal Epistemology: A Guiding Model. *Educational Psychologist*, *39*(1), 69–80. https://doi.org/10.1207/s15326985ep3901_7

Boon, M., & Baalen, S. van. (2018). Epistemology for Interdisciplinary Research – Shifting Philosophical Paradigms of Science. *European Journal for Philosophy of Science*, *9*(1). https://doi.org/10.1007/s13194-018-0242-4

Borrego, M., Foster, M. J., & Froyd, J. E. (2014). Systematic literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education*, *103*(1), 45–76. https://doi.org/10.1002/jee.20038

Bramer, W. M., Rethlefsen, M. L., Kleijnen, J., & Franco, O. H. (2017). Optimal database combinations for literature searches in systematic reviews: a prospective exploratory study. *Systematic Reviews*, *6*(1), 245. https://doi.org/10.1186/s13643-017-0644-y

Carberry, A. (2010). Work in Progress - Assessing Engineering Service Students' Characteristics. *IEEE Frontiers in Education*.

Carberry, A., Ohland, M., & Swan, C. (2010). A Pilot Validation Study of the Epistemological Beliefs Assessment for Engineering (EBAE): First-Year Engineering Student Beliefs. *American Society for Engineering Education*.

Chai, C. S., Khine, M. S., & Teo, T. (2006). Epistemological Beliefs on Teaching and Learning: A Survey Among Pre-service Teachers in Singapore. *Educational Media International*, *43*(4), 285–298. https://doi.org/10.1080/09523980600926242

DeBacker, T. K., Crowson, H. M., Beesley, A. D., Thoma, S. J., & Hestevold, N. L. (2008). The challenge of measuring epistemic beliefs: An analysis of three self-report instruments. *Journal of Experimental Education*, *76*(3), 281–312. https://doi.org/10.3200/JEXE.76.3.281-314

Faber, C., & Benson, L. C. (2017). Engineering Students' Epistemic Cognition in the Context of Problem Solving. *Journal of Engineering Education*, *106*(4), 677–709. https://doi.org/10.1002/jee.20183

Faber, C., Vargas, P., & Benson, L. (2016). Measuring engineering epistemic beliefs in undergraduate engineering students. *IEEE Frontiers in Education Conference*.

Finelli, C., & Borrego, M. (2015). *EER Taxonomy Version 1.0.* University of Michigan.

Frye, N., Montfort, D., Brown, S., & Adesope, O. (2012). I'm absolutely certain that's probably true: Exploring epistemologies of sophomore engineering students. *Frontiers in Education Conference Proceedings*, 1–6.

Ghazali, N. E., Bakar, Z. A., Shafie Bakar, M., Nur, T., Tengku, Z., Busu, M., Farahwahidah, N., Rahman, A., Effiyana Ghazali, N., & Abu Bakar, Z. (2021). Epistemology in Engineering Education: An Overview. In *ASEAN Journal of Engineering Education* (Vol. 5, Issue 2).

Green, H. J., & Hood, M. (2013). Significance of epistemological beliefs for teaching and learning psychology: A review. *Psychology Learning and Teaching*, *12*(2), 168–178. https://doi.org/10.2304/plat.2013.12.2.168

Hetherington, S. (Ed.). (2012). *Epistemology: the key thinkers*. Continuum International Publishers.

Hofer, B. K. (2000). Dimensionality and Disciplinary Differences in Personal Epistemology. *Contemporary Educational Psychology*, *25*(4), 378–405. https://doi.org/10.1006/ceps.1999.1026

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, *67*(1), 88–140. https://doi.org/10.2307/1170620

Kramer, A., Leonard, A., Desing, R., & Dringenberg, E. (2024). Beliefs in engineering education research: A systematic scoping review for studying beliefs beyond the most popular constructs. *Journal of Engineering Education*, 1–38. https://doi.org/10.1002/jcc.20583

Lonka, K., Sharafi, P., Karlgren, K., Masiello, I., Nieminen, J., Birgegård, G., & Josephson, A. (2008). MED NORD - A tool for measuring medical students' well-being and study orientations. *Medical Teacher*, *30*(1), 72–79. https://doi.org/10.1080/01421590701769555

Makhathini, T. P., Mtsweni, S., & Bakare, B. F. (2020). Exploring engineering students' epistemic beliefs and motivation: A case of a South African university. *South African Journal of Higher Education*, *34*(4). https://doi.org/10.20853/34-4-3625

Mengist, W., Soromessa, T., & Legese, G. (2020). Method for conducting systematic literature review and meta-analysis for environmental science research. *MethodsX*, *7*, 100777. https://doi.org/https://doi.org/10.1016/j.mex.2019.100777

Montfort, D., Brown, S., & Shinew, D. (2014). The personal epistemologies of civil engineering faculty. *Journal of Engineering Education*, *103*(3), 388–416. https://doi.org/10.1002/jee.20050

Muis, K. R., Bendixen, L. D., Haerle, F. C., Muis, K. R., Bendixen, · L D, & Haerle, F. C. (2006). Domain-Generality and Domain-Specificity in Personal Epistemology Research: Philosophical and Empirical Reflections in the Development of a

Theoretical Framework. *Educ Psychol Rev*, *18*, 3–54. https://doi.org/10.1007/s10648-006-9003-6

Palmer, B., & Marra, R. M. (2004). College student epistemological perspectives across knowledge domains: A proposed grounded theory. In *Higher Education* (Vol. 47).

Petticrew, M., & Roberts, H. (2006). Systematic Reviews in the Social Sciences: A Practical Guide. In *Systematic Reviews in the Social Sciences: A Practical Guide* (Vol. 11). https://doi.org/10.1002/9780470754887

Pintrich, P. (2002). Future challenges and direction for theory and research on personal epistemology. *Personal Epistemology: The Psychology of Beliefs about Knowledge and Knowing*.

Tan, E., Barton, A. C., & Benavides, A. W. (2019). Engineering for Sustainable Communities: Epistemic Tools in Support of Equitable and Consequential Middle School Engineering. *Science Education*, *103*(4), 1011–1046. https://doi.org/10.1002/sce.21515

Turns, J., Atman, C. J., Adams, R. S., & Barker, T. (2005). Research on engineering student knowing: Trends and opportunities. *Journal of Engineering Education*, *94*(1), 27–40. https://doi.org/10.1002/j.2168-9830.2005.tb00827.x

Yildirim, T. P., Besterfield-Sacre, M., & Shuman, L. J. (2010). *Estimating the Impact of Epistemological Beliefs on Modeling Ability*. https://api.semanticscholar.org/CorpusID:146561160

Yu, J. H., & Strobel, J. (2011). Instrument Development: Engineering-specific Epistemological, Epistemic and Ontological Beliefs. *Proceedings of the Research in Engineering Education Symposium*.

Yu, J. H., & Strobel, J. (2012). A First Step in the Instrument Development of Engineering-related Beliefs Questionnaire. *American Society for Engineering Education Conference*.