Using Q Methodology to Capture Variations in Perspectives in Engineering Education

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Introduction

This full methods paper examines how Q methodology has been applied within engineering education research and analyzes what these applications reveal about both the method's potential and its current limitations in this field. Although Q methodology has been recognized as a systematic approach for studying subjectivity and shared viewpoints in educational research [1], [2], its use in engineering education research remains relatively recent and methodologically uneven.

Q methodology is a mixed methods research approach that uses statistical techniques to uncover subjective viewpoints [3], [4], [5]. It combines elements of quantitative and qualitative research to define shared viewpoints among persons, rather than to measure how items rank relative to one another [3], [6], [7]. The goal of Q methodology is to understand variations and viewpoints amongst a population, rather than focusing on trends, averages or generalizations. It uncovers patterns of subjectivity that are difficult to obtain using qualitative methods alone, while also allowing closer exploration of marginalized viewpoints that might be obscured in quantitative approaches emphasizing averages [8], [9]. Large sample sizes are unnecessary in Q methodology because statistical insights are derived from the number and coherence of the ranked statements, not the number of participants.

Recent work suggests that the use of Q methodology in broad education research has increased over time with a growing number of studies published in more recent years [9]. Within engineering education, early applications have explored a variety of topics including doctoral career pathways [10] and engineering workforce preparation [11], [12]. Other studies highlight the potential of Q methodology for examining subjectivity in engineering education, including revealing diverse experiences and perspectives [6], [13], [14].

Despite its strengths, effective use of Q methodology depends on careful theoretical grounding. Methodological choices shape how subjectivity is represented and interpreted requiring attention to statement selection and qualitative interpretation of emergent factors. Q methodology is sometimes misunderstood, for example when it is treated primarily as a quantitative clustering technique or when statistical outputs are emphasized at the expense of interpretive analysis. These challenges may be more common in engineering education research, where many researchers have been trained in technical disciplines using quantitative, positivist approaches [15].

This paper reviews existing publications of Q methodology to address two research questions: How is Q methodology being applied in engineering education? What methodological gaps or misalignments exist in the current literature? For each publication, we evaluate these questions by identifying (1) the purposes for using Q methodology, (2) the research design and data collection methods, and (3) the data analysis methods, including approaches to factor interpretation and reporting. Rather than serving as a general primer on Q methodology, this work critically examines existing studies in order to develop methodological guidance specific to engineering education research. Recommendations are offered for researchers seeking to use Q methodology to study subjectivity and lived experience in engineering education contexts.

Methods

Applications of Q Methodology in Engineering Education

Existing applications of Q methodology in engineering education were identified by reviewing the literature. Our search focused on peer-reviewed journals and conference proceedings relevant to engineering education and crosschecked the ERIC database using "Q methodology" and "engineering education" as search terms. Publications were included if they explicitly applied Q methodology within an engineering education context and were published in peer-reviewed journals or conference proceedings. Studies from other STEM fields or published in non-educational outlets were excluded. References of the identified publications were screened to identify any additional studies meeting the inclusion criteria. Titles and abstracts were screened for relevance, and full texts were examined to confirm eligibility.

We extracted details about each study including topics, construction of Q-statements, sample size and participant characteristics from each publication. In total, 14 publications met the inclusion criteria and are summarized in Table 1. These studies were published across seven different journals and conference proceedings between 2014 and 2025. Approximately half of the studies were conducted in the United States, about a quarter in Denmark, and the remaining quarter in other countries. The information collected from each study forms the basis for examining patterns and trends in Q methodology studies in engineering education throughout the remainder of this paper.

Table 1: Engineering education studies applying Q methodology

Paper	Authors	Year	Publication	Topic
A	J. Chen, X. Du, A. Guerra, F. M. F. da Silva, and Y. Chaaban [5]	2024	Journal of Engineering Education	Academic well-being in a PBL (project-based learning) environment
B	L. N. d'Escoffier, D. Jiang, A. Guerra, A. F. V. Pineda, and I. Abou-Hayt [16]	2024	European Journal of Engineering Education	Competencies for sustainable development in PBL context
C	R. M. Desing and R. L. Kajfez [6]	2020	ASEE Annual Conference	Using Q Methodology in Engineering Education Research
D	X. Du, A. Lundberg, M. A. Ayari, K. K. Naji, and A. Hawari [17]	2021	Journal of Engineering Education	Aspects of PBL process important for learner agency
E	K. Ehlert and M. Orr [13]	2019	IEEE Frontiers in Education (FIE) Conference	Student perceptions of learning in cooperative education experiences
F	D. A. Hening and D. A. Koonce [11]	2015	International Conference on Operations Excellence & Service Engineering	Soft skills for engineers to succeed in a work environment

G	S. Hug and W. Chi [7]	2023	ASEE Annual Conference	Interpretations of diversity amongst cybersecurity students
H	R. L. Kajfez, C. M. Croyle, A. N. Snyder, and M. J. Mohammadi-Aragh [10]	2014	ASEE Annual Conference	Job positions and search process for engineering education PhDs
I	Y.-L. Liu, H.-P. Yueh, T.-L. Chen, and H.-J. Sheen [12]	2015	International Journal of Engineering Education	Professional competencies of the nanotechnology workforce
J	N. E. R. Lyngdorf, X. Du, and A. Lundberg [14]	2023	European Journal of Engineering Education	First-year engineering students' learner agency sources in a systemic PBL environment
K	J. F. Morton, T. R. Feyijimi, and S. J. Bork [18]	2025	ASEE Annual Conference	Engineering perceptions among first-year students from low-income schools
L	B. Nørgaard, J. Chen, C. K. Smink, A. Guerra, and X. Du [19]	2024	European Journal of Engineering Education	Engineering educators' professional learning in a PBL cross-institutional program in Africa
M	S. E. Ramlo [20]	2015	Mid-Western Educational Researcher	Q methodology for program assessment
N	P. E. C. Valles, S. Jimenez, L. Houghtalen, and M. R. Kendall [21]	2025	ASEE Annual Conference	Prioritizing aspects of engineering leadership

Overview of Q Methodology

This section briefly describes Q methodology for those unfamiliar with the method while more complete descriptions can be found in existing primers [3], [4].

Topic and Purpose: The first step for any research paper intending to use Q methodology is to select an appropriate topic. While traditional qualitative methods also explore subjectivity, Q methodology uniquely forces participants to prioritize their viewpoints relative to one another using a structured sorting grid, and then statistically clusters individuals who sort statements similarly. This makes it a valuable way to examine variation in viewpoints within a population by identifying shared perspectives among subgroups. It is particularly well suited for identifying minority perspectives and complex or conflicting viewpoints within populations. Q methodology has been applied across a wide range of disciplines including health, public policy, environmental studies, communication, and education, to explore people's beliefs, attitudes and perspectives [4], [9]. It is especially useful in educational contexts where learning is shaped by individual experiences and perspectives. The approach makes it possible to capture the different ways students and educators interpret their experiences and to explore complex, sometimes conflicting perspectives while minimizing researcher bias [9]. Equitable access to education is a major concern, and Q methodology is uniquely positioned to uncover perspectives that may not align with dominant or majority views [8]. In engineering education contexts, this makes it useful in examining experiences or viewpoints that are often underrepresented in survey-based research, including those of students with non-normative pathways, minoritized identities, or differing educational goals.

Research Design and Data Collection: As with any methodology, careful alignment between research goals and methodological choices is essential. Ontological orientations within this approach reveal important differences in the way subjectivity is theorized. In Q methodology, subjectivity is understood as patterned responses that an individual takes up by ranking pre-defined statements [21]. Descriptively, these statements illuminate participant viewpoints, perspectives, or opinions. These subjective positions are then communicated through the more "objective" groupings within Q-factor analysis. Together, both describe the individual and collective viewpoints found in a participant sample. Within the method, there are three traditions of individual and collective concepts of subjectivity. First, Stephenson theorized that subjectivity emerges from the self and is facilitated through the Q-sort [22]. This approach treats subjectivity as something to be observed through the Q-sort. A second approach, under Brown, believed that subjectivity is understood through normative and shared moral framings that are identified through factor analysis [4]. Contradictions are expected in groups, highlighting the pluralistic knowledge between individuals. In a third, more constructivist approach, Watts & Stenner, determined that subjectivity originates from the situated and sociocultural processes within a group, which only occurs during the moment of the Q-sort [3]. These ontological orientations subtly shape how researchers design and interpret their research.

Ontological differences also influence whether quantitative or qualitative methodologies are emphasized. While some research teams lean into statistical claims of validity, others utilize supplemental qualitative data collection methods, such as post-sorting interviews, to validate the results. Despite the attention placed on subjectivity within Q methodology, there remain analytical limits to the perspectives that are considered "significant" through the statistical factor analysis criteria [4]. Viewpoints that are characterized as "insignificant" may lack a strong shared meaning between participants, but are nonetheless still present and informative. Studies that triangulate the quantitative results with the additional qualitative data collection measures have richer and more contextually grounded interpretations of the viewpoints within the factor analysis. However, the ontological divisions within Q methodology have left this up to researchers to decide, and engineering educators should be aware of the way these differences shape their research design.

Statement Construction: Q methodology requires participants to rank statements relative to one another using a forced distribution rather than rating items in isolation [3]. Curating a statement list typically involves two steps: assembling the Q-concourse and narrowing to a smaller Q-set. The creation of the Q-concourse and Q-set are subjective processes that merit methodological scrutiny. The Q-concourse is a collection of statements that contain the full range of discourse about the topic, or "the ordinary conversation, commentary and discourse of everyday life" [4, p. 94]. The creation of the concourse is typically an inductive process, derived from interviews, literary and popular media, informal discussions, and/or extensive searches of academic literature. While the majority of Q-studies focus on verbal or text-based discourses, the concourse may include any type of media, including images, music, and film. The ultimate goal of Q methodology is to "reveal the inherent structure of the concourse" [4, p. 95] including variations in viewpoints and lines of thinking amongst the community under study.

Once the Q-concourse has been assembled, the research team selects a smaller subset of statements that are representative of the full concourse, called the Q-set or Q-sample. The process for curating a Q-set varies depending on the context, however, the main requirement is that the resulting set be of a manageable length for research participants (typically 40-80 statements) and that those statements retain the "comprehensiveness" of the larger Q-concourse [3, p. 75]. Assembling the Q-concourse and the Q-set is itself a complex and subjective process; research teams often describe in detail how these steps were achieved in order to demonstrate the comprehensiveness of the resulting Q-set.

Sample Size: The group of participants who will sort the statements are known as the P-set.The P-set should be a heterogeneous group, numbering in the tens, selected to reflect diverse viewpoints and characteristics [4], [23]. Large numbers of participants are not required in Q methodology because the goal is to highlight key opinions of the participant group rather than to identify trends. This makes Q methodology a practical approach for schools and programs with small enrollments, where obtaining the large numbers of responses typically needed for traditional surveys can be difficult. Q methodology is often described as an inversion of R methodology. R methodology is the traditional factor analysis used in surveys where statements are correlated across many participants to identify generalized trends. In contrast, Q methodology inverts this traditional factor analysis, treating the statements as constants and the participants as the variables.

The appropriate size of the P-set is a topic of debate among Q methodology scholars. Some recommend fewer participants than statements in the Q-set, based on the view that Q-factor analysis is a direct inversion of R methodology [6], [24]. Others argue that the P-set size should be determined by the need to adequately represent each anticipated factor. Since generally Q methodology results in two to five factors and often aim to include four or five participants per factor, this approach suggests a sample size of approximately eight to twenty-five participants, depending on the study and number of statements [6], [11], [24]. A prior systematic review of Q methodology studies in K-12 education reported P-set sizes ranging from 6 to 100 participants, with an average of just over 37 [9], suggesting that P-sets of 20 – 40 participants are typical [5].

The Q-Sort Procedure: The primary data collection instrument is the Q-sort, which captures participant subjectivity by requiring them to rank statements on a forced, quasi-normal distribution grid (Figure 1). This structure forces participants to make deliberate choices at the extremes, where fewer placements are available [25]. Q-sorts may be completed using either paper-based or computer-based methods and are often followed by interviews or written reflections to gather additional qualitative insight.

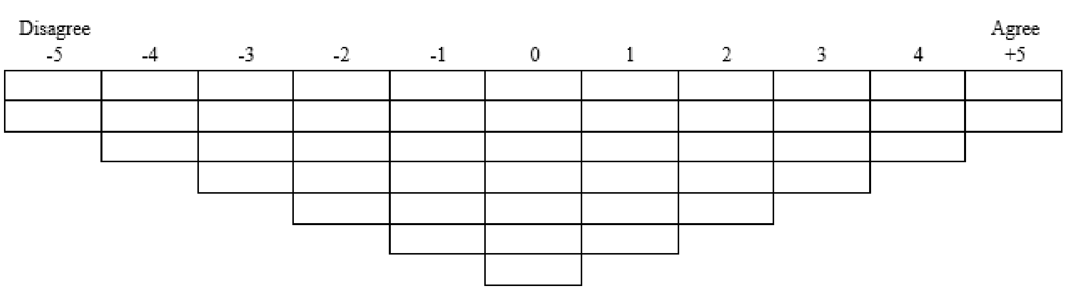

Figure 1: Example of an empty Q-sort response grid

Data Analysis & Factor Interpretation: After all participants have completed the Q-sort procedure, most Q methodology studies use a software tool to run the statistical analysis and generate the subgroups, which are known as "factors". Each factor represents a shared viewpoint, and contains clusters of participants who sorted the statements in similar ways. While this may seem like a purely quantitative process, researcher judgment is still an important factor. During this phase, researchers navigate key methodological decisions, such as selecting between different types of factor analysis (centroid v. PCA) and factor rotation (hand-rotation v. varimax) [3]. Establishing the number of meaningful factors typically involves statistical measures such as Eigenvalues and factor loadings. The research team must also decide what to do with individuals who load on to multiple factors (referred to as "confounded loading") or do not load onto any factor group (called "insignificant loading") [3].

The final interpretive phase involves analyzing the core differences and similarities between factors and providing a summary of each factor group. This is an interpretive process that requires careful consideration of the position of statements on the sorting grid relative to the other factors. Distinguishing and consensus statements, extreme rankings and participant comments are typically considered when interpreting the factor results. For this reason, Q methodology studies typically collect a post-survey interview and/or qualitative comments from participants to help the research team extract participant meanings and explain their sorting decisions [4]. The process of factor interpretation is strongly related to the ontological orientation of the research design, with some teams leaning more heavily into qualitative forms of validation of the factor groups.

In the following sections, this paper will analyze the fourteen Q methodology papers in engineering education with respect to each of these research areas: 1) the purpose of the research study, 2) research design and data collection, and 3) data analysis and factor interpretation. A comprehensive overview of the study parameters for all fourteen papers is provided in Appendix A. We conclude with recommendations for future work in engineering education.

Purposes for Using Q Methodology in Engineering Education

Publications in engineering education show that Q methodology has been applied to a range of topics including student and instructor experiences in project-based learning (*Papers A, B, D, J* and *L*) and professional preparation and workforce readiness (*Papers F, I and N*) (See Table 1). Two of the publications, *Papers C and E*, served primarily to familiarize the field with Q methodology. Additional studies examined program strengths and weaknesses for accreditation (*Paper M*), job search experiences of engineering education doctoral graduates (*Paper H*), students' views on diversity in cybersecurity (*Paper G*), and perceptions of college preparedness based on high school experiences (*Paper K*).

While the topics addressed in the literature are generally appropriate for Q methodology, the method was sometimes used for purposes that align more closely with descriptive or survey approaches, such as sorting by demographic characteristics or reducing long lists. Half of the studies collected some form of demographic data to provide contextual grounding for participant perspectives (*Papers A, B, G, H, J, K and N*). This information was used in a way consistent with Q methodology's person centered orientation in most cases to effectively support the analysis.

However, in one study (*Paper H)* demographic data appeared to play a more central role, overshadowing the factor groupings from the Q methodology. When understanding demographic groupings is the primary goal, other methods may be more appropriate. Other studies (*Paper I*) used Q methodology primarily to narrow or rank lists of priorities, competencies, or attributes. Although it can facilitate structured comparison among viewpoints, using Q methodology mainly for list reduction or prioritization underutilizes its core strength in revealing how participants structure meaning around complex issues. For example, using Q methodology merely to rank a list of top engineering skills eliminates minority viewpoints, failing to capture skills that a smaller proportion of participants might consider crucial. This issue is also discussed in greater depth in the section related to statement construction practices.

Research Design & Data Collection

Ontological Approaches to Subjectivity and Research Design

Of the three various framings of subjectivity within the tradition, seven of the studies *(Papers C, D, E, F, H, M and N)* grounded their study in Brown's theoretical framing. *Papers A, B, J, K, and L* took up Watts and Stenner's methodology. *Paper G* only cited Brown within the traditions of Q methodology. Finally, *Paper I* described steps from all three scholars' theories of Q methodology. Explicitly identifying the ontological tradition that aligns with a study's approach can help researchers better understand the construction of subjectivity within their own work.

Ontological differences are also revealed in the selection of qualitative and quantitative research designs. For instance, *Paper G*, described their study as qualitative, where additional demographic information was collected along with follow-up interviews from participants to develop deeper understandings into the individual perspectives found within the population they were studying. Whereas, *Papers D, F, I and M* only conducted a Q-sort; *Paper E* compared the participant groupings generated by Q methodology with those generated by cluster analysis algorithms. In addition to conducting the Q-sort, *Paper B, H, and N* asked participants to provide demographic information. The remaining studies favored supplemental qualitative data collection to further illustrate subjective perspectives located within the studies. For instance, *Papers J and K* collected additional data in a post sorting reflection activity including demographic data of participants; *Paper B and L* included a post survey that also required few open ended responses to better understand participant perspective. *Paper C* asked participants to participate in an interview to describe why they ranked specific statements. Finally, in *Paper A* demographic data of the participants was collected and the researchers completed their own reflections throughout all of the study procedures, which were deemed useful in understanding participant behaviors and viewpoints. *Papers A, D, I, and N* described the omission of a post sorting activity in their data collection as either a limitation or a future direction to take. For studies that value a deeper understanding of participants' viewpoints that were taken up in the Q-sort, we recommend a post sorting activity such as an interview or a reflection.

A Critical Review of Statement Construction Practices

Engineering education studies have, thus far, utilized only verbal and text-based media and tend to rely heavily on academic literature to construct the Q-concourse. Only two papers in our sample generated statements from interviews and/or observations of students (*Papers H & M*). Three studies collected statements from documents such as job advertisements (*Paper G*), curricular requirements from university websites (*Paper I*), and accreditation materials (*Paper M*). The remaining authors utilized academic literature reviews (*Papers A, B, C, K and L*), existing conceptual frameworks (*Papers E, F and N*), and personal experience (*Papers D and K*).

The process of narrowing the comprehensive Q-concourse to the more manageable Q-set is discussed in most engineering education studies; however, in some cases it is omitted or only briefly mentioned. The process of narrowing the list of statements amongst the papers in this sample includes discussion and consensus amongst the research team (*Paper B, D, K, L and N*), review of the Q-set by experts in the field (*Papers A, B, H, I, J, and L*), and running pilot Q-sorts (*Papers A, D, H, I, J, and L*). Many studies describe eliminating "similar", "overlapping", or "irrelevant" statements (*Papers A, B, C, J, L, and N*) as a result of expert reviews and pilot studies. In the interest of "comprehensiveness", two studies describe making efforts to ensure representation from each major category of the Q-Concourse (*Papers C and F*), known as "structured sampling" [24, p. 48]. In addition, two authors mention "smoothing" the language of the original Q-concourse so that statements make sense as stand-alone statements and as a set (*Papers B and C*).

There are many ways of going about curating the Q-set, and as scholars in the field have noted it is "more an art than a science" [4]. However, transparency around how these decisions were made is important. One curation process that is not recommended is eliminating less popular statements from the Q-set. During pilot Q-sorts, researchers commonly add or remove a few statements as a result of participants' interpretation of wording, comprehensiveness, and similar or overlapping concepts. However, one research team chose to use the pilot Q-sort as an elimination strategy (*Paper I*), in which only the positively ranked statements were retained; all negatively ranked statements were removed, winnowing a list of 120 statements to 47. In this case, it is necessary to remember the overall objective of Q methodology, which is not to identify *popular* viewpoints, but to identify *variations* in viewpoints. There may be subgroups of the population who would not have ranked the eliminated statements negatively, and the study could have unwittingly eliminated important minority perspectives.

High quality statement construction in engineering education involves an inductive process for gathering the Q-concourse statements and a systematic and transparent process for curating the Q-set. As such, the creation of the Q-concourse and Q-set are complex and time-consuming processes, and this should be balanced with realistic expectations of methodological rigor. The recommendation of this paper is that whatever process researchers follow, it is important to document these steps.

Sample Size and Viewpoint Variation

The P-sets in the engineering education studies generally align with standard recommendations, with half of the studies falling within the typical range of 20 to 40 participants (*Papers B, C, D, E, F, L, and M*; see Appendix A). Four studies included fewer than 20 participants (*Papers G, H, I, and N*), though one (*Paper N)* presented a pilot study and outlined plans for a larger, more diverse sample set in future work. A small number of studies exceeded the upper bound of 40 participants. In two of these cases, the larger overall numbers reflect study designs targeting distinct subgroups in which the individual subgroups remained near the recommended P-set size (*Papers A and K*). *Paper J* reported the largest P-set by including all students enrolled in a large course.

To date, Q methodology in engineering education has been primarily used to examine student perspectives. Across the studies included in this review, most (9 of 14) focused predominantly on students drawn from readily available groups, such as students enrolled in the same course or all members of a small department. In *Papers F and M*, an alumni or faculty participant was included alongside the student responses. These are examples of convenience sampling, which is practical; however, purposive sampling that ensures a variety of participants and viewpoints and avoids mixing participants with different roles might have produced more representative factors. Fewer studies focus on recent graduates (*Papers C and H*), engineering professionals (*Papers I and N*), or engineering educators (*Paper L*). While student perspectives are important, including professionals and educators as participants is valuable, since their viewpoints can help inform curriculum and practice. Furthermore, participant groups should be formed using stratified purposeful sampling rather than random or convenience sampling, as recommended in *Paper C*, to make certain variation in viewpoints is achieved [6].

Overcoming Quantitative Bias in Factor Interpretation

Amongst the engineering education papers, the typical practice for reporting Q-sort results is to provide a brief summary for each factor group along with distinguishing statements for that factor. Several studies also report consensus statements across multiple factors (*Paper A, D, I, J, L, and M*). If qualitative comments were collected, factor groupings were often illustrated using quotes from participants. Five studies did not conduct post-survey interviews or include qualitative comments in the survey (*Papers E, F, H, M and N*), which resulted in more perfunctory factor descriptions. Since many of these papers were conference papers, some were constrained by page limits (*Papers E, F, H and N*) or results were withheld (*Papers C and K*).

However, there is wide variation in how much detail authors include about how factors were selected, with some leaning into either the quantitative aspects or qualitative aspects. On the quantitative side, several high quality studies go into great detail to explain the specific factor analyses that were run, report eigenvalues, and include tables for individual factor loadings (*Papers A, B, H, I, J, and L*). On the qualitative side, *Papers D and J* describe discussions they had amongst the research team regarding how many factors were sufficient and whether the factors made sense. In one interesting example of a qualitative-leaning study, the statistical analysis did not generate significant factors, but the research team came to a consensus on factor groupings amongst themselves (*Paper D*). *Papers E, G and M* report statistically significant factors without discussion of how they were selected in either quantitative or qualitative terms.

Similarly, there is also substantial variation in reporting how factors were interpreted. Qualitative-leaning studies emphasize this process more than others. The best examples utilize the post-sorting interviews or qualitative data to make sense of the factor grids and describe the process of coming to consensus on the factor descriptions amongst the research team (*Papers D, J and L*). *Paper G* conducted a full qualitative data analysis of the interview data to support their interpretation of the factor groupings. *Paper B* used quantitative means to explain the factor significance using the Z-score variance which measures consensus within each factor. Some studies offer only limited discussion of this process (*Paper I and N*) or neglect to mention it altogether (*Paper E, F, and M*).

The interpretive flexibility of Q methodology can be seen as a strength, allowing researchers from both quantitative and qualitative backgrounds to take it up. However, there is a need in engineering education research to explain in greater detail the factor selection and interpretation steps, whether in quantitative or qualitative terms. There is a tendency amongst some papers in this sample to treat these final steps as a purely quantitative exercise. Although statistical analysis is employed, the interpretation of factors is essentially a qualitative process and attention should be paid to the decisions that are made amongst the research team in selecting factors and interpreting what they mean.

Conclusion and Recommendations

Q methodology offers a systematic approach for uncovering shared and divergent perspectives in engineering education. It is a valuable tool for exploring subjectivity and can capture minority viewpoints that may be overlooked in typical quantitative methods. Our review of 14 engineering education studies reflect wide variability in how Q methodology is applied, with gaps that may limit its potential. We observed a tendency to misalign the method as a simple list-reduction tool, under-theorize the foundational concept of subjectivity, lack transparency and inductive source use in statement construction and treat factor interpretation as a purely quantitative exercise. To address these gaps, we offer the following recommendations to optimize the use of Q methodology in engineering education research:

- Align Q methodology with research questions focused on subjectivity and variations in perspectives to avoid misusing the method for mere list-reduction or generalizations based on demographic data.
- Align with the ontological tradition coordinated with the research approach and collect supplemental qualitative data to appropriately interpret subjectivity.
- Assemble the Q-concourse inductively using diverse source types rather than relying solely on academic literature.
- Construct the Q-set systematically and document the process rather than using reduction strategies that are ambiguous or lack transparency.
- Report both the quantitative criteria and the qualitative discussions that shape factor selection and interpretations to avoid treating these as primarily statistical exercises.

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References

[1] C. T. Gooding, “Q Technique as an Effective Measure of Teacher Attitudes,” *J. Teach. Educ.*, vol. 22, no. 1, pp. 44–47, Mar. 1971, doi: 10.1177/002248717102200110.

[2] D. Montgomery, “Q Applied to Educational Issues,” *Operant Subj.*, Jan. 2010, doi: 10.22488/OKSTATE.10.100572.

[3] S. Watts and P. Stenner, “Doing Q Methodology: theory, method and interpretation,” *Qual. Res. Psychol.*, vol. 2, no. 1, pp. 67–91, Jan. 2005, doi: 10.1191/1478088705qp022oa.

[4] S. R. Brown, “A Primer on Q Methodology,” *Operant Subj.*, vol. 16, no. 3/4, Apr. 1993.

[5] J. Chen, X. Du, A. Guerra, F. M. F. da Silva, and Y. Chaaban, “Sources contributing to engineering students’ academic well-being: An exploration using the Q methodology,” *J. Eng. Educ.*, vol. 113, no. 3, pp. 576–602, Jul. 2024, doi: 10.1002/jee.20605.

[6] R. M. Desing and R. L. Kajfez, “How to Use Q Methodology in Engineering Education Research,” presented at the 2020 ASEE Virtual Annual Conference Content Access, Jun. 2020.

[7] S. Hug and W. Chi, “Students’ Complex Perspectives on Diversity—A Mixed Methods Pilot Study,” presented at the 2023 ASEE Annual Conference & Exposition, Jun. 2023.

[8] K. Pike, P. Wright, B. Wink, and S. Fletcher, “The assessment of cultural ecosystem services in the marine environment using Q methodology,” *J. Coast. Conserv.*, vol. 19, no. 5, pp. 667–675, Oct. 2015, doi: 10.1007/s11852-014-0350-z.

[9] A. Lundberg, R. de Leeuw, and R. Aliani, “Using Q methodology: Sorting out subjectivity in educational research,” *Educ. Res. Rev.*, vol. 31, p. 100361, Nov. 2020, doi: 10.1016/j.edurev.2020.100361.

[10] R. L. Kajfez, C. M. Croyle, A. N. Snyder, and M. J. Mohammadi-Aragh, “Engineering Education Ph.D. Students: Where Are They Now and What Was the Job Search Process Like?,” presented at the 2014 ASEE Annual Conference & Exposition, Jun. 2014, p. 24.496.1-24.496.15.

[11] D. A. Hening and D. A. Koonce, “Important Soft Skills for Engineers to Succeed in a Work Environment,” presented at the International Conference on Industrial Engineering and Operations Management, Dubai, United Arab Emirates (UAE), Mar. 2015.

[12] Y.-L. Liu, H.-P. Yueh, T.-L. Chen, and H.-J. Sheen, “Identifying Nanotechnology Professional Competencies for Engineering Students Using Q Methodology,” *Int. J. Eng. Educ.*, vol. 31, no. 5, pp. 1389–1397, 2015.

[13] K. M. Ehlert and M. K. Orr, “Comparing Grouping Results Between Cluster Analysis and Q-Methodology,” in *2019 IEEE Frontiers in Education Conference (FIE)*, Oct. 2019, pp. 1–3. doi: 10.1109/FIE43999.2019.9028444.

[14] N. E. R. Lyngdorf, X. Du, and A. Lundberg, “First-year engineering students’ learner agency sources in a systemic PBL environment: a Q study,” *Eur. J. Eng. Educ.*, vol. 48, no. 6, pp. 1130–1147, Nov. 2023, doi: 10.1080/03043797.2023.2233427.

[15] M. Borrego, “Conceptual Difficulties Experienced by Trained Engineers Learning Educational Research Methods,” *J. Eng. Educ.*, vol. 96, no. 2, pp. 91–102, 2007, doi: 10.1002/j.2168-9830.2007.tb00920.x.

[16] L. N. d’Escoffier, D. Jiang, A. Guerra, A. F. V. Pineda, and I. Abou-Hayt, “Engineer Students’ Views on Competencies for Sustainable Development: A Case from a Systemic PBL Environment Using Q Methodology,” *Eur. J. Eng. Educ.*, vol. 49, no. 5, pp. 928–944, 2024, doi: 10.1080/03043797.2024.2388122.

[17] X. Du, A. Lundberg, M. A. Ayari, K. K. Naji, and A. Hawari, “Examining engineering students’ perceptions of learner agency enactment in problem- and project-based learning using Q methodology,” *J. Eng. Educ.*, vol. 111, no. 1, pp. 111–136, 2022, doi: 10.1002/jee.20430.
[18] J. F. Morton, T. R. Feyijimi, and S. J. Bork, “Exploring Engineering Perceptions Among First-Year Undergraduate Students from Low-Income Schools: A Mixed Methods Study,” presented at the 2025 ASEE Annual Conference & Exposition, Jun. 2025.
[19] B. Nørgaard, J. Chen, C. K. Smink, A. Guerra, and X. Du, “Engineering educators’ professional learning for educational change in a PBL-base and cross-institutional programme in Africa: a Q-study,” *Eur. J. Eng. Educ.*, vol. 49, no. 2, pp. 236–256, Mar. 2024, doi: 10.1080/03043797.2023.2250738.
[20] S. E. Ramlo, “Q Methodology as a Tool for Program Assessment,” *-West. Educ. Res.*, vol. 27, no. 3, pp. 207–223, 2015.
[21] P. E. C. Valles, S. Jimenez, L. Houghtalen, and M. R. Kendall, “Using Q-Sort to Prioritize Concepts for Inclusion in an Engineering Leadership Development Assessment Instrument: A Work in Progress,” presented at the 2025 ASEE Annual Conference & Exposition, Jun. 2025.
[22] W. Stephenson, “Correlating Persons Instead of Tests,” *J. Pers.*, vol. 4, no. 1, pp. 17–24, 1935, doi: 10.1111/j.1467-6494.1935.tb02022.x.
[23] J. Sandling, “Q Methodology: Complete Beginner’s Guide | JONATHAN SANDLING.” https://jonathansandling.com/q-methodology-complete-beginners-guide/
[24] F. Dziopa and K. Ahern, “A systematic literature review of the applications of Q-technique and its methodology.,” *Methodol. Eur. J. Res. Methods Behav. Soc. Sci.*, vol. 7, no. 2, pp. 39–55, Jan. 2011, doi: 10.1027/1614-2241/a000021.
[25] A. Zabala, C. Sandbrook, and N. Mukherjee, “When and how to use Q methodology to understand perspectives in conservation research,” *Conserv. Biol.*, vol. 32, no. 5, pp. 1185–1194, 2018, doi: 10.1111/cobi.13123.

Appendix A: Table summarizing methodological details of identified engineering education studies using Q methodology

Paper	Authors	Topic	Tradition of Subjectivity in Q Methodology	Additional Data Collection Steps	Q-Concourse Sources	Q-Set Curation	No. Statements + Grid Size	Sample Size	Factor Explanation	Factor Selection	Factor Interpretation
A	J. Chen, X. Du, A. Guerra, F. M. F. da Silva, and Y. Chaaban	Academic well-being in PBL	Watts & Stenner	Demographic Data; Researcher reflections	Academic literature review	Expert review, Pilot Q-sorts	31 -4 to +4	42 students (Subgroups of 23 and 19)	Summary, Distinguishing statements, Consensus statements, Participant quotes, Demographic trends	Type of analysis, Eigenvalues, Factor Loadings	Research team consensus
B	L. N. d'Escoffier, D. Jiang, A. Guerra, A. F. V. Pineda, and I. Abou-Hayt	Sustainable development competencies in PBL	Watts & Stenner	Post screening survey; Demographic survey	Academic literature review	Consensus discussions, Language smoothing	36 -5 to +5	26 master students	Summary, Distinguishing statements, Participant quotes	Type of analysis, Eigenvalues, Factor Loadings	Z-score variance
C	R. M. Desing and R. L. Kajfez	Q methodology in engineering education research	Brown	Post sorting interview	Academic literature review	Structured sampling, Language smoothing	50 -5 to +5	20 recent graduates	No results	No results	No results
D	X. Du, A. Lundberg, M. A. Ayari, K. K. Naji, and A. Hawari	PBL process and learner agency	Brown	None	Academic literature review, Personal experience	Research team consensus, Pilot Q-sorts	40 -5 to +5	39 undergraduate engineering students	Summary, Distinguishing statements, Consensus statements, Participant quotes, Demographic trends	Research team consensus	Research team consensus
E	K. Ehlert and M. Orr	Q methodology and cluster analysis comparison	Brown	Cluster analysis	Existing conceptual frameworks	Not mentioned	42 -3 to +3	28 students	Summary	Not mentioned	Not mentioned
F	D. A. Hening and D. A. Koonce	Engineer soft skills for workplace success	Brown	None	Existing conceptual frameworks	Structured sampling	65 -5 to +5	20 (19 engineering students and 1 recent alumni)	Summary, Distinguishing statements	Type of analysis, Eigenvalues, Factor Loadings	Not mentioned
G	S. Hug and W. Chi	Diversity perceptions among cybersecurity students	Brown	Demographic Survey; Follow up interviews	Job advertisements, Curricular requirements	Not mentioned	30 -3 to +3	16 high-achieving scholarship students	Summary, Distinguishing statements, Participant quotes, Demographic	Not mentioned	Qualitative Data Analysis

									trends		
H	R. L. Kajfez, C. M. Croyle, A. N. Snyder, and M. J. Mohammadi-Aragh	Engineering education job search and positions for recent graduates	Brown	Demographic Survey	Interviews, Observations	Expert review, Pilot Q-sorts	30 -3 to +3	13 recent engineering education PhD graduates	Summary, Distinguishing statements, Demographic trends	Type of analysis, P-values	Not mentioned
I	Y.-L. Liu, H.-P. Yueh, T.-L. Chen, and H.-J. Sheen	Professional competencies of the nanotechnology workforce	Brown, Stephenson, Watts & Stenner	None	Curricular requirements	Expert review, Pilot Q-sorts	47 -5 to +5	12 professionals in nanotechnology industry	Summary, Distinguishing statements, Consensus statements, Participant quotes	Type of analysis, Eigenvalues	Limited description
J	N. E. R. Lyngdorf, X. Du, and A. Lundberg	First-year students' learner agency in PBL	Watts & Stenner	Demographic Survey; Post sorting survey	Academic literature review	Expert review, Pilot Q-sorts	39 -5 to +5	102 first-year students	Summary, Distinguishing statements, Consensus statements, Participant quotes, Demographic trends	Type of analysis, Eigenvalues, Factor Loadings, Research team consensus	Research team consensus
K	J. F. Morton, T. R. Feyijimi, and S. J. Bork	Engineering perceptions of first-year students from low-income schools	Watts & Stenner	Demographic Survey: Post sorting reflection activity	Academic literature review, Personal experience	Research team consensus	35 -4 to +4	≥ 60 (proposed but not yet recruited)	No results	No results	No results
L	B. Nørgaard, J. Chen, C. K. Smink, A. Guerra, and X. Du	Educator professional learning in cross-institutional PBL in Africa	Watts & Stenner	Post sorting survey	Academic literature review	Expert review, Pilot Q-sorts, Research team consensus	34 -4 to +4	40 engineering educators	Summary, Distinguishing statements, Consensus Statements, Participant Quotes, Demographic trends	Type of analysis, Eigenvalues, Factor Loadings	Research team consensus
M	S. E. Ramlo	Q methodology for program assessment	Brown	None	Interviews, Learning outcomes, Accreditation documents	Faculty & student feedback	48 -5 to +5	35 (34 students, 1 faculty)	Summary, Distinguishing statements, Consensus statements	Not mentioned	Not mentioned
N	P. E. C. Valles, S. Jimenez, L. Houghtalen, and M. R. Kendall	Prioritizing aspects of engineering leadership	Brown	Demographic survey	Existing conceptual frameworks	Research team consensus	60 -6 to +6	7 engineering leaders and managers	Summary	Type of analysis, Eigenvalues	Limited description