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Common Characteristics of High-quality Papers Studying Student Response to Active Learning*

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Active learning is increasingly used in engineering classrooms to improve student learning and engagement. Although students tend to respond positively to the introduction of active learning, some instructors experience negative student responses. Determining why and how to alleviate such negative responses is an open research question. Because there are many contextual variables to consider, we believe this question will best be addressed by increasing the number of faculty who are able to study their own implementation of active learning. This paper examines the underlying characteristics of 27 high-quality papers on student response to active learning. Using a six step research framework, this paper: (1) discusses common categories of research questions, (2) offers rules of thumb for literature reviews, (3) provides example theories, (4) discusses the data collected by qualitative, quantitative, and mixed methods studies and how the data is analyzed, (5) points to different approaches for data presentation, and (6) lists elements which authors typically include in their description of context and discussion sections. We offer literature-driven recommendations for faculty to help them quickly adopt good practices for how to share evidence based on their experiences.

Keywords: active learning; student response; systematic literature review

1. Introduction

Many engineering instructors are incorporating active learning into traditionally lecture-based classrooms. Active learning can take many forms, such as quick questions or pauses to compare notes with a partner (see [1] for a good overview of types of active learning). Active learning is known to increase student learning, improve student retention, especially for those who are underrepresented in engineering, and lead to several affective benefits such as improved engagement and interest, e.g., [2, 3]. Despite the many proven benefits of using active learning, many instructors remain hesitant to adopt active learning, with 55% of science, technology, engineering, and mathematics (STEM) classrooms being lecture dominant [4]. The reasons for not adopting active learning that instructors cite include poor student study skills, class time constraints, lack of preparation time, and fear of negative student response [5]. Refs. [1] and [6] address the two time concerns, and [7] summarizes the literature on student *affective* responses (e.g., as reflected in students' satisfaction, attitudes, or engagement), concluding that students typically respond positively to active learning. Further, [8] outlines practical instructor strategies that reduce the likelihood of negative responses.

Although most research supports a positive student response to active learning, every context is unique, and negative responses remains a possibility. The engineering community should continue studying the implementation of active learning to determine the underlying causes of negative responses and to identify ways to alleviate the negative responses. Many instructors in the classroom have taken it upon themselves to research student response to active learning, but the approaches to tackling this research are inconsistent and unclear. To assist researchers in understanding how to study active learning, this paper addresses the following research question: *what are the common characteristics of high-quality papers that address affective student response to active learning?*

This paper builds on a previous systematic literature review on student response to active learning, which assigned a coarse quality score to 412 papers [7]. There is growing interest in systematic literature reviews in engineering education literature; however, reviews tend to focus on student learning, with very few investigating research methods or research

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paper characteristics [9]. Here, we select 27 of the highest scoring papers and use a six-step research framework to provide a more in-depth view into how the 27 papers: (1) designed research questions, (2) reviewed the literature, (3) integrated theory, (4) analyzed data, (5) interpreted evidence, and (6) disseminated the research. We conclude by summarizing guidance for faculty wishing to design and conduct their own study on student response to active learning.

The contribution of this paper is to offer an approachable, literature-driven perspective for conducting high-quality research on student response to active learning. There are many workshops and textbooks that help faculty learn how to do research; this paper does not replace those references. Rather, this paper complements those resources, because it concentrates on a specific topic of interest, is easily accessible, and presents concrete examples. Despite the diversity inherent in the 27 publications that form the corpus of this project, we think it will be helpful to have example papers as guidelines, and we insert various examples as references for readers.

2. Six-Step Research Framework

For each of the 27 papers in our sample, we analyzed how the paper met the steps in the National Research Council's (NRC) framework for quality research [10]. Our results section is organized by the six steps (see Fig. 1):

1. *Articulate research questions* (RQs). The RQs define the goal and are the backbone for the entire study.
2. *Review the literature*. A thorough literature review surveys and synthesizes previous work to overview current knowledge on a topic, describes previous research methods, overviews applicable theories, and/or identifies gaps in the research.

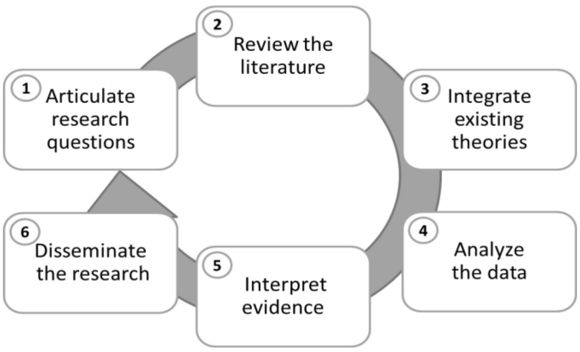

Fig. 1. Overview of the six-step research framework this paper uses to analyze the 27 studies in our sample [10].

3. *Integrate existing theories*. Solid theoretical underpinnings can strengthen research by guiding the work and serving as an interpretive lens. Over time, the broader research community accumulates knowledge by supporting, refining, or refuting existing theories.
4. *Analyze the data*. Though STEM faculty are often more familiar with quantitative research methods, mixed methods and qualitative approaches are also useful in addressing questions on student response. The choice of a proper method is driven by the RQ and theory, and it is often an iterative process.
5. *Interpret evidence*. Well-established research offers a coherent and explicit chain of reasoning that connects theory and evidence. Researchers align data to RQs and existing theories to make sense of the data and convince readers of the efficacy of their findings.
6. *Disseminate the research*. Sharing work and inviting peer review (e.g., through a workshop, presentation, or research paper) are critical to building knowledge in a research community. This step involves outlining context, methodology, and findings; describing the alignment between RQ, theory, and results; highlighting key limitations; and offering ways the findings might generalize to other settings.

The NRC framework aligns with key ideas about quality research from other major sources, e.g., [10]. However, the framework is not without its faults, and it has been criticized as emphasizing positivist concepts and privileging quantitative methodologies over qualitative ones [12]. Despite its limitations, we believe the NRC framework provides a good starting place to investigate research quality, especially since we take a qualitative approach to examining each of the steps within the framework.

3. Sample

To address our research question (what are the common characteristics of high-quality papers that address affective student response to active learning?), we examined a select group of 27 high scoring papers from a systematic literature review (SLR). The full SLR methodology is described in [13], and the corresponding summary of results is in [7]. Briefly, the SLR project involved: (1) creating an initial keyword search of five research databases; (2) combing through the resulting pool of 2,365 studies to see which involved an active learning intervention, were in an undergraduate STEM class, measured an effective response, and were published as journal articles or conference papers in English from 1990–2015; and (3) coding the

Table 1. Description of the 11-point quality rubric applied to QN and QL papers. MM papers were assigned the QN score if they were primarily quantitative. For MM papers with a substantial qualitative component, the papers earned $\frac{1}{2}$ point for each of the starred quantitative and quantitative items (up to 6 points total), one point for discussing limitations, and one point for each of the following MM specific criteria: combined analysis of data, used more than two data sources, cited MM sources for data analysis, discussed rationale/ purpose for MM, and discussed relationship between the QN and QL data.

Quantitative (QN)	**Qualitative (QL)**
Study design (3 pts)	
• included a pre/post design* • included a control group* • included multiple class sections for comparison	• involved multiple researchers* • acknowledged following IRB procedures* • described methods for data analysis
Sampling/data sources (3 pts)	
• sample size greater than 200 or over 50% participation rate • used more than one data source • applied a validated instrument	• described sampling strategy or provided rationale for studying the course* • used more than one data source • described data collection protocol
Results presentation (4 pts)	
• included survey questions used for data collection* • reported percentages responding in different ways* • reported statistical significance* • reported effect size*	• included excerpts of the data* • discussed the study's broader context* • discussed student characteristics • discussed researchers' positionality*
Discussion (1 pt)	
• discussed limitations	• discussed limitations

remaining 412 papers on aspects such as methodology and conclusion. The SLR categorized the 412 studies according to the primary methodology employed in the work:

- Quantitative studies (QN) relied primarily on numerical data interpreted through descriptive or inferential statistical analyses (N = 217).
- Qualitative studies (QL) primarily analyzed participants' verbal or written comments or narrative observational data through a qualitative interpretive lens (N = 45).
- Mixed methods (MM) included features of both quantitative and qualitative studies (N = 150).

The SLR project scored each of the 412 full papers according to a "quality rubric" for each methodology based on published criteria for good research and for systematic reviews [7]. To avoid re-coding all 412 papers, the quality scoring we used for the large number of quantitative papers and quantitative-heavy mixed methods papers was entirely based on criteria collected as part of the SLR. However, we re-coded qualitative papers and mixed methods papers having a heavy qualitative focus (N = 41) to include qualitative-focused items that we did not originally code for in the SLR. Two researchers coded a qualitative and mixed methods paper and compared notes. Then one researcher coded all the qualitative papers while the other researcher coded all the qualitative-heavy mixed methods papers, helping to ensure scoring consistency across papers within the same primary methodology. Table 1 presents an overview of the quality rubrics and Fig. 2 shows the distribution of quality scores.

For our present dataset, we noticed there was a gap in quality score for all methodologies after the top nine scoring papers, so we chose the nine papers within each primary methodology that scored highest on the quality rubric. We refer to these 27 studies as QN1–QN9 (quantitative studies), QL1–QL9 (qualitative studies), and MM1-MM9 (mixed meth-

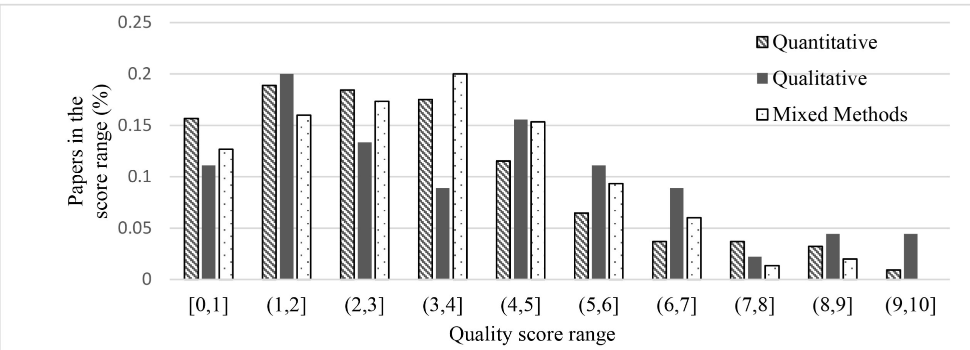

Fig. 2. Distribution of quality scores for the 412 studies in the SLR. The minimum number of points for papers in this study was 8.5 for quantitative and 7 for qualitative and mixed methods.

ods studies). The citations for the 27 papers are included in Appendix 1. The majority of the studies (N = 23) are journal articles, including three from the *International Journal of Engineering Education*, two from each of three journals (*Interactive Learning Environments*; *Journal of Science Education & Technology*; and *PRIMUS: Problems, Resources, and Issues in Mathematics Undergraduate Studies*), and 14 others (each from a distinct journal). The other four papers are from conference proceedings, with three from the *American Society for Engineering Education (ASEE) Annual Conference & Exposition*.

4. Application of the Six-step Quality Framework

We examined each of the 27 studies included in our study to determine whether and how it addressed each step of the six-step research NRC framework. The following sections describe the coding process, summarize our results, and highlight papers that exemplify good practice. For some steps, we found guidelines in the literature (discussed in each section) to direct our coding. For other steps, we took an inductive approach by listing features of the step that we identified in the 27 papers, open coding the features to identify similar factors between papers, and then grouping the factors according to how frequently they were mentioned. Since every step had many noteworthy studies, we chose the examples in each section to provide a variety of perspectives.

4.1 Articulate Research Questions

A well-crafted research question (RQ) defines the goal for a study and dictates the study's design. Fourteen of the 27 studies listed explicit RQs; while the remaining studies included implicit or explicit objectives that could be analyzed as RQs. We categorized the RQs for the 27 studies according to the four types defined by [14]: *what works, what is, visions of the possible*, and *formulating new conceptual frameworks*.

"*What works*" questions probe the effectiveness of different teaching practices by asking, for example, whether a specific teaching method (e.g., using clickers) achieves a desired goal (e.g., increasing student participation). These questions tended to be phrased like hypotheses, using language like "will" or "does." Some example "w*hat works*" questions are:

- Does the introduction of a problem-based learning curriculum affect students' perceptions of the learning environment? Does it result in student affective outcomes? Do changes in perception help explain changes in outcome? (QN4)
- "Can we measurably and positively change conceptual understanding and attitudinal outcomes. . . by using discipline-specific physics examples?" (MM6, p. 231)
- "Will the use of clickers in instruction improve student attitudes toward the use of instructional technology in science classes?" (QN9, p. 653)

"*What is*" questions focus on describing the current state of an aspect of the classroom (e.g., student learning). These questions tended to use "how" or "in what ways" language. Some example "*what is*" questions/objectives are:

- "In what ways do pedagogical choices made by engineering instructors assist students to develop attitudes and behaviors associated with self-regulated learners?" (MM2, p. 606)
- "How do students perceive the contribution of studying E&M [electricity and magnetism] in one format or the other to their learning in advanced courses?" (QL3, p. 302)
- To examine "the flipped classroom's influence on student academic, student peer-to-peer and student-faculty involvement" (QL5, p. 42)

A few studies included both "*what works*" and "*what is*" questions. None of the studies used "*visions of the possible*" questions (e.g., "how might incorporating peer instruction impact student interaction in my class?") or "*formulating new conceptual frameworks*" questions (e.g., "what themes emerge from studies on students use of clickers in a classroom that might help us understand how pauses in lecture impact students developing conceptual understanding?"). These questions are likely less common, but they could be used by faculty when designing new pedagogies or studying concepts not confined to a classroom setting. The data analysis section discusses the relation between research question and study methodology.

We direct readers to QN5 as a good example of referencing research questions throughout the paper. The authors compared traditional, online, and flipped sections of an introductory statistics course "taught by the same instructor during the same semester and with the same assignments and assessments" (p. 7). The "what works" RQs were: Do changes in attitudes toward statistics, changes in statistical reasoning, student performance, and/or student perceptions of the course/instructor tend to vary across sections? (p. 7). The authors referred to these RQs throughout the paper, e.g., the table on p. 11 connected each RQ to its data sources and the results section was split up into sub-sections by RQ (p. 15–22).

Table 2. Example theories used in the 27 papers

Theory	Description
Experiential learning theory [20]	Students learn through experiences in an often-cyclic process involving concrete experience, reflection, abstract conceptualization, and active experimentation.
Social cognitive theory [21]	Personal beliefs, behaviors, and the environment shape learning. Students learn from others through interactions and demonstrations.
Model of educational productivity [22]	There are nine influential variables for students' achievement, grouped by student characteristics, home environment, and instructional variables.
Self-determination theory [23]	Autonomy, competence, and relatedness effect intrinsic and extrinsic motivation.
Theory of student involvement [24]	Students learn best and are more satisfied when they are involved. Discusses high-value forms of involvement.
Self-regulated learning [25]	Student learning improves when they take proactive actions such as generating motivation to learn, active use of learning strategies, and reflection.

4.2 Review the Literature

Literature reviews can and should vary based on audience, publication venue, and the paper's purpose. We present statistics based on the 23 studies (out of 27) which had stand-alone literature reviews for readers to reference as "rules of thumb." We grouped the statistics according to the key characteristics of literature reviews outlined in [15]:

1. The *length* varied significantly, with the word count ranging from 113 to 2,496 words (mean = 927, standard deviation = 702).
2. The *number of citations* ranged from 5 to 56 (mean = 24, standard deviation = 16).
3. *Purpose* and *topics:* Most studies presented research on active learning (12 on the specific type used in their paper and nine on general active learning results). Studies with a relevant theory frequently provided a rationale for it in their literature review. Finally, roughly half of the studies used the literature review to justify or motivate their research.
4. The *types of sources* cited included a focus on journal papers (17/23), conference proceedings (2/23), and a mix of both (4/23). Some studies also cited books and national reports, but these were less common.
5. *Timeframe*: 19 studies included publications within the past 10 years.

QN1 and QL2 have (admittedly longer) literature reviews that address topics which are likely helpful to other researchers and that show how literature reviews can cover a variety of purposes/topics. QN1 examined how using clickers in a math classroom impacted students' math anxiety. The literature review was organized into subsections on: math anxiety (describing it, summarizing previous results, introducing the instrument they use to measure it, and overviewing previous methods to address it), clickers (describing their common use and listing benefits and drawbacks), and the possible indirect relationships between the two topics. The author compared the claims to those from the literature in the discussion section (p. 466).

QL2 studied how students responded when a novice instructor redesigned a third-year structural design course to be project-based. The background section reviewed the cognitive and affective benefits of general active learning and project-based learning more specifically. They overviewed previously observed reasons for student resistance in classrooms, especially those directly caused by instructor decisions, and presented their theories. The literature review section foreshadowed the instructor's good intentions for the class and the mistakes made that led to negative student responses. The authors' conclusions reiterated the benefits of active learning from the literature, encouraged instructors to implement it, and offered recommendations to avoid the observed student resistance.

4.3 Integrate Existing Theories

Theories[1] can guide the definition of RQs, organize research, and serve as a lens to interpret results [16, 17]. Table 2 lists and provides a short description for several theories used in the 27 studies that are likely to apply to other similar projects. This is by no means a comprehensive list, but it may provide a starting place. There are also many resources that provide short overviews on learning theories, e.g., [18].

MM3 provides an example of using a theory to design an intervention and to analyze data. The authors used the main principles embedded in Dewey's Experiential learning theory, (continuity, social control, individual freedom, purpose, and dynamic organization; see MM3, p. 547), to design three implementations of a first-year computer science course with varying amounts of experiential learning activities. They used a preexisting framework with 10 criteria (tied to Dewey's

[1] The terms "conceptual framework," "theory," "theoretical framework," and "framework" are used inconsistently in the literature. We use simply "theory" and acknowledge that this is a simplification of a relatively complex topic.

principles) to organize and analyze their data, and their results section primarily consisted of analyzing differences in student reaction within these 10 categories across the three course sections. The authors found that, as Dewey would predict, the interactive and student control elements motivated students and made them more interested in learning.

As another example of how to integrate theory, QL5 used Astin's student involvement theory to explore how three specific types of involvement (academic involvement, involvement with peers, and involvement with faculty) manifested in flipped classrooms. The authors defined the theory, provided findings from previous research on how student involvement can improve student outcomes and satisfaction, and returned to Astin's theory in the discussion to suggest that their observed increase in involvement in flipped classrooms is theorized to result in positive student outcomes and satisfaction.

4.4 Analyze the Data

The 27 papers were purposefully chosen to include qualitative, quantitative, and mixed methods papers, and RQs and data analysis look different for each methodology. Few papers discuss why they chose a specific methodology, therefore, we direct readers to [19], and the references therein, for help deciding on a methodology.

Most of the quantitative papers had "what works" questions, did not include a theory, and used surveys (often with Likert questions) for data collection. Authors used statistical methods such as ANOVAs (see QN5 for a good example), factor analysis, normalization, modeling, and hierarchical linear modeling (see QN8 for a good example) for data analysis.

Including the mixed methods papers, 10 of the 14 papers with a quantitative instrument used a previously validated survey to measure student affective response, while the other four authors created their own instruments. Validated instruments make it easy to compare results across studies and assess the validity and reliability of a study [10]. Table 3 overviews some of the instruments that are likely to apply to other projects related to affective student response. MM9 is a good example for incorporating an existing survey instrument; the authors used a subset of the Pittsburgh Engineering Attitudes Scale-Revised to investigate whether incorporating research in a material science course impacted student attitudes toward engineering. Instead of including the full instrument, the authors described the factors measured and provided details about validity and psychometric testing (p. 1494).

The qualitative papers included more "what is" questions and about half included a theory (see the previous section for examples). The papers had a wide range of data sources. For example, QL4 used free response entries in student feedback forms, QL9 used interviews, QL6 designed an open-ended survey for students to respond to, and QL2 used open-ended surveys, focus groups, interviews, and document analysis. Most of the qualitative papers used open-coding to analyze the resulting data, where researchers ascribe a "code" or label to a piece of data, group data by these codes, evaluate and refine codes, iterate until they reach a consensus, and then organize the final codes into themes.

Table 3. Example validated survey instruments to measure student affective response used in the 27 studies

Name and citation	Description
Colorado Learning Attitudes about Science Survey – Biology [26]	Survey for attitudes toward science. Factors include real world connections, personal interest, sense making, conceptual connections, and problem solving. There are different versions for physics, chemistry, and biology.
Pittsburgh Engineering Attitudes Scale – Revised [27]	28-questions for students' attitudes about engineering. Seven factors: general impressions, financial influences, societal contributions, social prestige, enjoyment of math and science, engineering as an exact science, and parental pressure.
Survey of Attitudes Toward Statistics [28]	28-questions to measure students' attitudes toward statistics. Four factors: students' feelings about statistics, cognitive competence, the value of statistics, and difficulty.
Intrinsic Motivation Inventory [29]	45-questions to measure subjective experience during a specific activity. Seven factors: interest/enjoyment, competence, effort, value, pressure, perceived choice, and experiences of relatedness.
Motivated Strategies for Learning Questionnaire [30]	81-questions with two sections. Motivation measures intrinsic and extrinsic goal orientation, task value, perceived control of learning, self-efficacy, and test anxiety. Learning strategies measures cognitive and resource management strategies.
The Derived Chemistry Anxiety Rating Scale [31]	36-questions to measure anxiety associated with chemistry. Three factors: learning anxiety, evaluation anxiety, and handling chemicals anxiety.
Maryland Physics Expectations Survey [32]	34-questions to assess student expectations in physics courses. Six factors: independence, coherent structure, learning concepts versus problem solving, relevance to the real world, the role of math, and effort expectations.
Learning Climate Questionnaire [33]	15-questions with a single factor. Used to assess student perceptions of how much instructors support student autonomy.

Many of the qualitative papers also included a member checking step, where results were shared with participants to get their feedback.

Mixed methods studies incorporate elements from both quantitative and qualitative methodologies, though to varying degrees. For example, MM1 used the qualitative and quantitative data to a similar extent, MM2 primarily used a quantitative method, but then used qualitative data to further explore an observation from their quantitative results, and MM6 primarily used interviews, with quantitative survey data to support their findings.

We highlight MM6 as an example of a mixed methods study. MM6 asked "can we measurably and positively change conceptual understanding and attitudinal outcomes of our student population by using discipline-specific physics examples?" (p. 231). In their methodology section (pp. 233–234), they authors give an overview of each quantitative instrument and what they measured with it, then explained how they selected students to interview (a mix of purposeful and random sampling). For both types of data, the authors explained when they collected the data and if/how students were incentivized to participate. The results section presented more specific methodology on how they analyzed the data just before presenting the end-product of each analysis. The "student attitudes" section (pp. 12–14) interleaves the discussion of qualitative and quantitative results to address a single topic.

Regardless of the methodology, research papers should include a clear methods section so that other researchers can replicate or build on a study, to explain how the chosen methodology aligns with the RQs, and to allow the reader to judge the validity of the study. Overall, twenty studies at least partially satisfied all four of the methods criteria laid out by [34]:

1. Include *study design* that explains the connection between the methods and the RQs.
2. List any decisions made in choice of *data source*, including participant selection and selecting which data to analyze.
3. Note any tools or methods used for *data collection* and explain the rationale or procedure for determining relevant variables.
4. Define or describe all *data analysis* procedures.

4.5 Interpret Evidence

For this step, we focused on data presentation as the most observable element of interpreting evidence in a research paper. Good data presentation enhances the reader's ability to understand and interpret data. Ten of the papers that analyzed qualitative data organized their interviews, focus groups, or open-form data into themes and presented the data by theme. A good example of the theme organization is QL4, which analyzed 6,010 comments from students across 10 classes using a flipped teaching style about their experiences. Despite the large dataset, the authors kept the results section concise (p. 1041–1044) by organizing it into themes (e.g., in-class learning) and sub-topics (e.g., "alignment with pre-class learning" and "the role of the instructor"). They presented their data by incorporating many single-line quotes and a select number of longer excerpts, allowing the reader to connect to the diverse experiences presented while maintaining a single, readable story.

All but one of the papers that presented quantitative data did so with tables (including descriptive statistics, results from t-tests or factor analyses, and advanced statistical tests such as ANOVA and regression analyses). In addition, seven papers presented data through figures (e.g., graphs, scatter plots, boxplots, or radar chart).

MM5 is a good example of quantitative and qualitative data presentation and of incorporating tables and figures throughout the paper. For example, a flowchart overviewed the re-design process of the non-majors introductory biology course (p. 5) and a table in the findings (p. 12) listed the attitudinal survey items, the pre-and post-percentage of students who agreed with each, and whether the change was significant. The findings section (pp. 10–18) is organized into themes that emerged from the survey and focus group analysis. The learning experience theme (pp. 13–14) did a particularly good job combining data types. Finally, a table summarized the key takeaways and connected the findings and conclusions sections (p. 15). In contrast, although MM9 used a qualitative survey to inform their quantitative survey design, making the overall study design mixed methods, the paper does not discuss the rationale for mixed methods and only presents the quantitative data.

4.6 Disseminate the Research

Dissemination can involve conferences, papers, or talking with colleagues. Because our data sample is research papers, we concentrate on dissemination through writing. Many of our other steps discussed specific sections of a research paper, and here we chose to concentrate on two important sections we have not yet discussed: the description of context and the discussion.

Describing the study's context allows readers to understand design decisions and judge if the findings are transferable. We present the results from our inductive analysis grouped by contextual focus as suggestions for what other authors should consider including:

- *Institution*: Most studies named or described the institution; papers that did not explicitly name the institution included more information about the university setting (e.g., enrollment). Some papers further discussed the culture and/or the motivation for implementing active learning at the institution.
- *Students*: Papers typically included either student demographics data or student year, course level, the most common student major, or a breakdown of student majors. Some papers additionally discussed the students' previous coursework, grades, or the pedagogy used in previous courses.
- *Course*: Almost all papers included high-level information about the course, the course name, or the course goals. Many papers mentioned class size and class times or number of contact hours per week.
- *Instructor*: Very few papers included any information about the instructor. Possibly, this is due to concerns for anonymity. A few papers mentioned that the instructor was new to active learning and discussed how this might have influenced the implementation.
- *Intervention*: Commonly included details were the purpose of the active learning, group size, and the role of the instructor/teaching assistant during the activities. Other characteristics include the way the activity was graded, examples of the activity or student's output, and the amount of time spent on active learning.

For authors outside of France, MM8 offers an example of describing an unfamiliar context. The background and methods section (pp. 2–3) highlighted major differences between the French and United States educational systems, described the university, and discussed recent charges in the student population that motivated the research. The settings and participants section (pp. 3–4) provided more detail on how the major system works, described the types of students, and listed the focus of the courses.

As another example, QL8 investigated the effects of using multiple assessments in abstract algebra courses. The authors identified the institution and instructor, described the students' common curricular background and their predicted career paths, and presented historical statistics on pass rates (p. 5). Most of the contextual description is on the assessments (pp. 5–8), and the authors balanced brevity and thoroughness by quickly reviewing common assessments and elaborating on rarer assessments.

In contrast, QL9 provides very few contextual details, likely due to concerns about anonymity of their few participants. We know only that the study took place in a "large, Midwestern university" and the gender and status (student, teaching assistant, or instructor) of the ten participants. The authors provide a few details on the timeline and instructor roles for the active learning intervention, but very few specific details on its implementation. Again, this is likely because a thorough description of the project would allow a reader to identify the course and therefore possibly a small pool of possible participants. The authors help to make up for this lack of detail by describing generic implementations of problem-based learning in the literature review.

The last section of a paper is the discussion and conclusion. This section should provide the reader with a deeper understanding of the results, implications, limitations, and areas for further research [35]. Within each of these sections, we noted:

1. All papers that had an explicit RQ *answered their RQ* in the discussion.
2. All papers included some *interpretation* of and/or *implications* for the study's results. The most common element was discussing how their results supported, contradicted, or were explained by the literature.
3. Most papers included explicit *limitations*. Some limiting factors were sampling issues (e.g., lack of randomization), study methodology (e.g., unvalidated instruments), small sample size, confounding variables (e.g., uncontrollable variability between two classes), and impact of researchers. There were fewer limited factors common across studies, with only "generalizability" and "the breadth of the study" appearing more than once.
4. About half of the papers included explicit suggestions for *future research*, typically as the last section in the discussion and occasionally by connecting future research with limitations, suggesting ways future studies could address identified limitations.

For readers interested in seeing an example discussion, we recommend QN9, which asked whether clickers improved "student attitudes toward the use of instructional technology" (p. 653). In their discussion (pp. 658–660), the authors reviewed the study's purpose and commented on how previous research led to the current project. Next, they addressed each research question in a separate sub-section. They discussed differences in their findings among the four classes studied, compared the results of their second RQ to the literature, and connected limitations to recommendations. The authors provided commentary and hypotheses about the impact of the limitations and the underlying cause for their results.

5. Discussion

Our research objective was *to identify the common characteristics of high-quality papers that address student affective response to active learning.* In doing so, we hope to enable researchers to quickly adopt literature-driven best practices for studying this important topic.

5.1 Limitations

We defined our methods, carefully read and pair-coded each of the 27 papers, and discussed coding results in groups to limit the impact of our biases, but research subjectivity remains a limitation of our study, as other researchers may judge the quality components differently. By only examining 27 papers in-depth, we may have missed some trends and examples in the literature. However, by keeping our study reasonably sized, we believe that we were able to provide a deeper investigation of the papers and point our readers to a few key examples for further reading.

Another limitation of our methodology is that we only use research papers as evidence. Thus, we were not able to analyze some steps in the research process; very few publications fully describe the iterative nature inherent in designing a study or what other steps they will take to disseminate their findings. Similarly, we originally planned to analyze whether the 27 papers in our study involved collaborating with education experts because there is clear evidence of the benefit of collaboration: papers with a social scientist on the authorship list have a full order of magnitude larger acceptance rates to the *Journal of Engineering Education* than those with all engineers [36]. However, collaboration does not always lead to co-authorship, so this was difficult to analyze with our data.

Additionally, we narrowed the scope of this paper by analyzing quality through the lens of the six steps in the NRC framework for quality. By using this framework, we avoided a self-fulfilling prophecy; our analysis of quality was not based on our initial quality rubric. However, this means we may have missed high-papers that did not score well on our initial, coarse rubric. Also, the NRC framework does not consider other qualities that are important to consider before beginning a research project, such as relevance, originality, and scope. Analyzing these (perhaps less observable, but just as important) qualities would make for an interesting future study.

5.2 Recommendations for Faculty

When conducting a research study, researchers must consider their purpose, audience, and venue. Many engineering instructors may be new to educational research in general or specifically to the idea of studying how their class responds to a change in teaching style. We hope this paper provides these faculty with a literature-driven set of suggested features for steps of their research paper, "rules of thumb" for writing their own paper, and examples for further reading. In summary, we offer the following suggestions, tied to the NRC framework for quality (Fig. 1):

1. *Research question*. Identify your initial RQ, while considering how it will impact your methodology. All of the papers we considered had "what works" or "what is" questions. Your RQ will directly influence your methodology and theory. We noted that most papers with "what works" questions tended to be quantitative and to not have an underlying theory, while papers with "what is" questions tended to be qualitative and include a theory.
2. *Review the literature*. This can justify your RQ, document what is already known, help you identify a relevant theory, or describe analytical models. Though the length of literature reviews varied significantly, most papers primarily referenced journal papers and included sources published within the past 10 years.
3. *Integrate existing theories*. For those new to incorporating a theory into a research project studying classroom response, we recommend reviewing the example papers highlighted in section 4.3 for how a theory can be used in the project planning, intervention design, and data interpretation stages. It is beyond the scope of this paper to discuss all relevant theories for projects about active learning; however, we provided examples of some theories used by other researchers in Table 2.
4. *Analyze the data*. After you select your primary methodology, we recommend looking for a validated instrument that can answer your RQ before designing your own. Table 3 may provide a starting point for identifying quantitative instruments to measure affective response. Qualitative and mixed methods analysis was more varied. Section 4.4 gives a quick overview of many papers and what data they used so that readers can hopefully find a similar study to use for reference. Finally, when communicating your work, the description of methods should include the study design, describe the data source, note methods for data collection, and define all data analysis [34].
5. *Interpret evidence*. We expect most STEM faculty are more familiar with working with quantitative data, statistical tests, and presenting data in tables and figures. When working

with qualitative data, consider organizing the data into themes and including quotes as evidence.

6. *Disseminate the research*. Contextual descriptions should be sufficiently detailed that a reader can determine if your results apply to another situation. As a starting point, consider describing the institution, students, course, instructor, and intervention (see section 4.6 for more specific ideas of what to describe for each of these). For the discussion section, we recommend following the guidelines in [35] by revisiting and answering your RQ, providing an interpretation or implication of your results, identifying limitations, and providing suggestions for future research.

6. Conclusion

Engineering education research is still a relatively new discipline. Further, the nature of the discipline lends itself to wide participation and interest from instructors, faculty, and researchers with different backgrounds. Our goal for this paper is that it provides a quick start guide for researchers who wish to study student affective response to active learning, an important and expanding area of study that often attracts researchers that are new to researching engineering education.

We went through each study and looked at it through the lens of the NRC's six-step research framework. All 27 studies had a research objective (though not always in the form of a RQ), a methods section, a presentation of data, a description of the context, and a discussion. However, the studies differed in important ways. The literature reviews ranged from non-existent to multi-page overviews of previous work. The extent to which the studies included a theory varied – only a third of the studies did – and when a theory was included, the way it was used differed (e.g., influencing data analysis or intervention design). Roughly half of the studies referenced or included the instrument or protocol they used, and these varied from validated to author-created ones. The examples provided in the previous sections should provide researchers with specific starting points for each of these six-steps. Much of the variation across the 27 high-quality studies can be attributed to the different audiences and purposes for the papers. Some papers concentrated on describing the active learning intervention for other faculty to replicate, and traded-off space on background or results, while other papers had more detailed results, but a higher-level description of the intervention. Neither of these approaches is inherently better than the other; both serve a different purpose.

While our examples all deal with student affective response to active learning, many of this paper's takeaways apply broadly to education research, and the analysis and examples could be a good basis for discussion for students and their advisers as they learn how to design and carry out a research project.

One direction for future research would be to expand this study to consider an in-depth view of quality in other areas of education research. Another interesting opportunity for a future study would be to take a longitudinal view of quality as engineering education research continues to mature as a discipline, perhaps building off a simple quality rubric that can be quickly applied to a large number of studies.

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Appendix I

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6.1. Quantitative

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