Conducting Sound, Equity-Enabling Computing Education Research

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ABSTRACT

Problem. To investigate and identify promising practices in equitable K-12 and tertiary computer science (CS) education, the capacity for education researchers to conduct this research must be rapidly built globally. Simultaneously, concerns have arisen over the last few years about the quality of research that is being conducted and the lack of research that supports teaching all students computing.

Research Question. Our research question for our study was: *In what ways can existing research standards and practices inform methodologically sound, equity-enabling computing education research?*

Methodology. We conducted a concept analysis using existing research and various standards (e.g. European Educational Research Association, Australian Education Research Organisation, American Psychological Association). We then synthesised key features in the context of equity-focused K-12 computing education research.

Findings. We present a set of guidelines for general research design that takes into account best practices across the standards that are infused with equity-enabling research practices.

Implications. Our guidelines will directly impact future equitable computing education research by providing guidance on conducting high-quality research such that the findings can be aggregated and impact future policy with evidence-based results. Because we have crafted these guidelines to be broadly applicable across a variety of settings, we believe that they will be useful to researchers operating in a variety of contexts.

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CCS CONCEPTS

• **Social and professional topics** → **Computing education**; **Computing education programs**; **Computer science education**.

KEYWORDS

Computer science education research, computing education, research, equity, high quality, evidence, standards, primary, secondary, K-12, tertiary, post-secondary

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1 INTRODUCTION

The United Nations Sustainable Development Goal 4 is to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" [41, p. 1]. Many countries have adopted this goal, with the National Research Council noting that equity should be at the “forefront of any effort to improve the goals, structures, and practices that support learning and educational attainment for all students” [105, p. 277]. This framing has been adopted across specific educational policies, standards, settings, curriculum, resources, and pedagogy, including computing education, to achieve CS for all students [134]. In particular, computing education in primary and secondary schools presents a unique opportunity to address existing inequities in the technology workforce, while also providing opportunities for critical thinking abound societal and individual impacts of technology on students.

But what is equity? According to Jurado de Los Santos et al.,

> The first reference made to the term “equity” was related to the need established by many countries . . . to

> bring together two terms—*equity* and *quality*—in the supply of education in each nation. . . . The conceptualisation of the term is twofold: on the one hand, those normative references confirm the fact that the principles of quality and equity are inseparable. This conceptualisation of equity is based on two principles: quality education for all citizens, seeking to develop to the maximum the individual, social, intellectual, cultural, and emotional capacities, always within a framework of effective equality of opportunity; and the shared effort of the entire education community in caring for the diversity of students. On the other hand, the term equity is associated with social well-being, based on the principle of personalised and universal education. In this case, equity and quality are considered to be two sides of the same coin. [77]

We define equity as *the multiple processes for ensuring that all learners have access to and participate in computing education with outcomes that are similar across various populations of students.* In our research study, we operationalize this definition by focusing on the roles Computing Education Research (CER), as well as researchers, play in providing evidence that enables those who create educational pathways to make decisions that support equitable access to, participation in, and experiences in computing [51].

Equity-enabling education research[1], or research that supports equitable educational outcomes, is necessary to provide the evidence needed for decision-makers and educators to advocate, support, and deliver computing education in K-12 classrooms that leads to equitable access, participation, and experiences (and therefore outcomes) among all students [51]. Equity-enabling education research, by its very nature and necessity, must meet quality standards to provide meaningful evidence for a given context.

> **Equity-enabling education research, by its very nature and necessity, must meet quality standards to provide meaningful evidence for particular contexts for which studies have been conducted.**

Concepts surrounding equity-enabling education research are not new. Research practices can ensure that dominant groups' perspectives, concerns, and preferences are embedded in educational systems, which clearly disadvantages students from groups who are non-dominant (and often marginalized or excluded) [53]. Montecinos notes that, in studies with all White participants, not presenting this information within publications makes "Whiteness" invisible, which by default then secures the *norm of Whiteness* [57, 100]. Similarly, Fernandez, referring to medical education research, notes that research should go beyond the "mean impact" and be purposeful and intentional in examining the wide range of promising practices for subgroups of learners that are defined by learning characteristics (e.g. prior learning experiences) as well as demographic characteristics [49].

Equity-enabling education research goes far beyond who is included in studies. It must come to terms with the researchers' sets of assumptions surrounding reality and knowledge of power dynamics [4], axiology (the role of values in research), and the dominant knowledge and power relationships [124]. Using certain research methods, such as ethnographic research, can contribute to equity and social justice in education [11]. Pearson et al. notes that "STEM fields have a history of conducting research, creating theories, and making measurements primarily focused on white, cisgendered, male, heterosexual, able-bodied, wealthy individuals" [115, p. 3]. Prioritising "the unique ontological, epistemological, and axiological positioning" of participants can further enable efforts to create equity-enabling education research that reflects their lived experiences [124]. Furthermore, the historical context, exclusionary practices, and legacy of nations determine who has traditionally been viewed as scientists, engineers, and mathematicians (that is, wealthy, able-bodied, male, cisgendered, heterosexual) and, therefore, must be acknowledged as a root of the lack of representation in these fields [115].

Our goal of raising awareness of the need for equity-enabling research (with guidelines on how to do so) is captured in our research question:

> *In what ways can existing research standards and practices inform methodologically sound, equity-enabling computing education research?*

To answer this question, we first conducted a review of the literature to identify how *equity* and *quality* are defined in the context of education research [34]. We then conducted a comparative review of published evidence standards for education research. We investigated each standard in light of existing research on equity and incorporated suggestions at each stage of conducting and reporting research to provide steps for achieving equity-enabling research.

Education research has grown over the last several decades in an attempt to meet the demands of teaching all students [49, 77]. Federal and private funders provide significant amounts of program support explicitly for equity-enabling research [32]. Supporting education researchers in their ability to conduct research in their unique settings and participants gives way for researchers to "systematically investigate issues related to their personal and community priorities" [105, p. 278]. Thus, this study is important to understand the role researchers play in producing CER that benefits all students.

2 DEFINING METHODOLOGICALLY SOUND, EQUITY-FOCUSED, AND HIGH-QUALITY RESEARCH

2.1 Defining equity in education research

In a 2020 study by Jurado de Los Santos et al., the authors conducted a systematic literature review to analyse the various ways equity has been incorporated into studies and reported [77]. Notably, the authors state that *equity* is difficult to define given the socio-political structures in society that may shift and form the term [77]. Once

[1]We acknowledge and thank Dr. Joseph Carroll-Miranda, University of Puerto Rico Rio Piedras, for introducing this terminology.

a working definition of equity is defined within the context of a project or body of work, how that definition is then operationalised must also be considered, particularly since no single study can investigate all factors that contribute to equity.

The term *equity* is often defined differently by educators and researchers based on the type of research they are conducting and their situational context (e.g. historical, geographical, social, religious, economic, cultural, political, environmental) [53, 91, 105, 115, 118, 145]. Matters of equity are inherently tied to power, which may be defined differently in countries that have varying governing and economic structures [53].

Countries heavily invested in capitalism may define equity in terms of investing "in the science and engineering education of underrepresented groups simply because American labour needs can no longer be met by recruiting among the traditional populations" [105, p. 278]. Countries heavily invested in social justice may define equity with a lens that "calls to remedy the injustices visited on entire groups of American society that in the past have been underserved by their schools and have thereby suffered severely limited prospects of high-prestige careers in science and engineering" [105, p. 278]. Within any country or region, both perspectives may be adopted as a means of achieving a common overarching goal and be diametrically opposed in the approaches taken to reach equity.

Even among collaborating researchers, how equity is defined and then operationalised can vary. Notions of equity have been found through the literature and have expanded over the last 70 years, with Jurado de Los Santos et al.'s systematic literature review findings indicating that in 1948-2006, fewer than 2% of articles studied equity across seven dimensions (i.e. gender differences, diversity, students, mathematics as a subject, education (general), resource allocation, and rank), with research mostly focused on aspects directly related to gender differences and equity in education. In the interval of 2017-2019, nearly 10% of articles studied equity across 22 dimensions (i.e. with respect to school administration, access policies, students with disabilities, race, and school choice) [77]. There has been a significant shift in research towards access to education, students with disabilities, teacher and student race, and teacher attitudes. This clearly indicates a significant upward trend in education research that is equity-focused, and the notable shifts indicate a greater understanding of the need to improve equitable outcomes among all students.

As expected, definitions of equity are plentiful. They include:

- "The process of reckoning with how historical events have shaped and continue to reinforce power imbalances, and actively working to dismantle those imbalances so that society can restructure itself to better sustain and empower all" [115, p. 21:es1, 3].
- "The guarantee of fair treatment, access, opportunity, and advancement, while at the same time striving to identify and eliminate barriers that have prevented the full participation of some groups. The principle of equity acknowledges that there are historically underserved and underrepresented populations and that fairness regarding these unbalanced conditions is needed to assist equality in the provision of effective opportunities to all groups" [135, p. 1].
- "Equity [in informal STEM education] implies fair access to resources (such as education) that advance social justice by allowing for self-determination and full participation in society" [53, p. 89].
- "Equity in computer science education can be defined as the absence of systematic disparities in educational outcomes between social groups who have different levels of underlying social advantage/disadvantage — that is, different positions in a social hierarchy" [116, p. 1].

Unfortunately, variations in the definition of equity have an impact on students learning computing [129]. For example, the gap in reporting student and teacher demographics, such as gender, race/ethnicity, and prior computing experience [97], means that it is unclear to what extent the dominant groups in studies are providing the evidence for educators and policymakers to make critical decisions about curriculum, pedagogy, standards, policies, funding, and supporting resources.

2.2 Defining high-quality in education research

Equitable research is an essential component of truly high-quality research. While the term *high-quality education* is common parlance among computing education and educational researchers, despite guidance on what constitutes *high-quality education*, there is no clear definition of the term. Some definitions have included preparing future and current educators to provide good instruction [45], creating a curriculum that considers the students' needs in terms of personal and cognitive capacity [161], accessing resources and using available resources effectively [25] and incorporating principles supporting diversity and inclusivity [38, 130].

Similarly, with respect to high-quality education research, a consensus definition has not been achieved. Past efforts to define this term include parameters used to describe the quality of research outputs (e.g. methodological rigour, reporting quality [48, 162]). According to Yarris et al., the terminology used by funding bodies to describe research outputs often includes relevance, rigour for outputs, and significance and reach for impact. However, measuring the quality of evidence can be subjective[65, 162] and vary by discipline. Evans et al. assert that there is a high level of variability in how quality standards are understood and interpreted [48]. For instance, factors such as the type of research question or quality indices applied in medical education may not be relevant for computing education.

Researchers measure quality based on research reports, usually in the form of published articles. The publication practice can result in a form of survivorship bias since researchers only rely on accepted reports, and acceptance is conditioned on a variety of factors (e.g. access, funding, novelty, prestige, statistical significance). It is important to recognise these gatekeeping issues when publishing research. While this may be inherently reductive, as it misconstrues quantity and popularity as quality, evidence has shown that scientific publication may be a reasonable indicator of quality [44, 126].

Reviews of CER literature have found gaps and challenges in the quality of reporting [69, 96, 97, 128]. Sound reporting is important to fully characterise research studies, explore the results, and describe the impact of the study. Additionally, sound reporting of key

results can support meta-analysis of multiple studies, furthering community understanding of computing education.

Margulieux et al. [92] performed a systematic literature review of measurements used in published CER between 2013 and 2017. The study analysed quantitative, qualitative, and mixed methods papers and found that the community employs several best practices related to evidence quality, such as collecting multiple different measurements to construct a complete understanding of phenomena, adopting or adapting instruments from other disciplines, creating CER-specific instruments, and having sufficient sample sizes and effect sizes for the type of data being analysed. However, the authors note that there are several practices that need wider adoption, such as collecting participant and learner characteristics, in particular with respect to prior learning, measuring time on task, and measuring process and product data. The study highlighted that there is a need for measurement standards, in particular through the availability of standardised instruments that measure constructs with evidence of reliability and validity.

3 METHODOLOGY

To address our primary research question, *In what ways can existing research standards and practices inform methodologically sound, equity-enabling computing education research?*, we engaged in a conceptual analysis of various research standards and practices. Our aim was to gain an in-depth understanding of conducting methodologically sound and equity-promoting research, and how this understanding can be applied to CER. We blend Petrina (which is theoretical) and Walker et al. (which is process-focused) to perform our conceptual analysis in a theoretically-based and practical manner [117, 157]. Our framing includes exploring the dilemmatic thesis, semantic resolution, dimensioning and mapping, referential framing, and representational provision. Each of these steps is described in more detail below and depicted in Figure 1.

3.1 Dilemmatic Thesis

As a first step, Petrina suggests defining the dilemma or problem with current meanings of the concept being studied [117]. Walker et al. calls for two steps to be conducted that align with this phase: selecting a concept and determining the aims or purposes of the analysis [157]. We chose to explore *how hiqh-quality education research is defined* as evidenced by methodological standards predicated on characterising *quality* and the extent to which equity-enabling guidelines were included. We chose to use standards across various countries to bring in international perspectives and with the recognition that those who have created national-level standards bodies had selected criteria for building strong evidence for decision-making. We deem this concept to be interesting, relevant, important, and useful, all of which are requirements set forth by Walker et al. [157]. We determined that the purpose of our analysis was to understand how other standards defined, supported, and advocated for methodological soundness in education research via guidelines to researchers with a lens toward developing an operational definition for equity-enabling research.

For equity practices in research, we conducted a review of the literature [34], including education research articles that were predicated on understanding how equity is and can be defined and used in research (more details in Section 3.7). We determined that the purpose of our analysis was to understand how others have defined, supported, and advocated for equity-focused education research.

3.2 Semantic Resolution

Semantic resolution considers the various meanings (common, obscure, etc.) that resolve in or through the concept over time [117].Walker et al. calls for one step that aligns with semantic resolution: identify all uses of the concept that are discoverable. To meet Walker et al.'s definition of identifying all uses of the concept that we can discover, we found standards through extensive online searches that included a varying set of English-speaking countries due to the languages primarily spoken by our research team[2] We used the following criteria:

- presented methodologically sound ways to conduct or report research,
- publicly available documents,
- presented in English,
- presented by a national-level or international-level standards body (either government-issued or professional association-issued (e.g. British Educational Research Association), and
- addressed education research.

We also sought to ensure that there was representation of standards from multiple countries. Our search resulted in the identification of 13 sets of standards that provide guidelines for conducting rigorous education research.

For the review of equity practices, we identified defining attributes as a set of basic research steps presented in an introduction to education research textbook [34] that also aligned with our experiences as researchers. We then conducted continual literature review searches to find equity-focused, education research practices to address each research step. These basic steps included identifying the research problem and questions, reviewing the literature, researcher reflexivity and positionality, research ethics, research methods, participant engagement, instrumentation and collecting data, analysing and interpreting data, and reporting on findings.

3.3 Dimensioning and Mapping

Petrina defines dimensioning and mapping as the various dimensions of the concept that give it definition [117]. Walker et al. calls for two steps that align with dimensioning and mapping: determine the defining attributes and identify a model case. For the first step, we identified common attributes across the standards and across our literature review categories (e.g. participant engagement, identifying a research problem) that we wanted to examine. This provided an organisational structure that we could use to analyse and synthesise similar standards.

While both Petrina and Walker et al. call for a model case to which all other cases are compared, we learned as we started our analysis process that it was more beneficial to compare and synthesise the results from data collection across each category. We identified key characteristics for conducting sound, equity-enabling

[2]Only using standards written in English is a limitation of our study. We recognise that many other countries have standards that are written in languages other than English. Despite our searches across multiple countries and multiple languages, these are the standards that provided the most comprehensive standards.

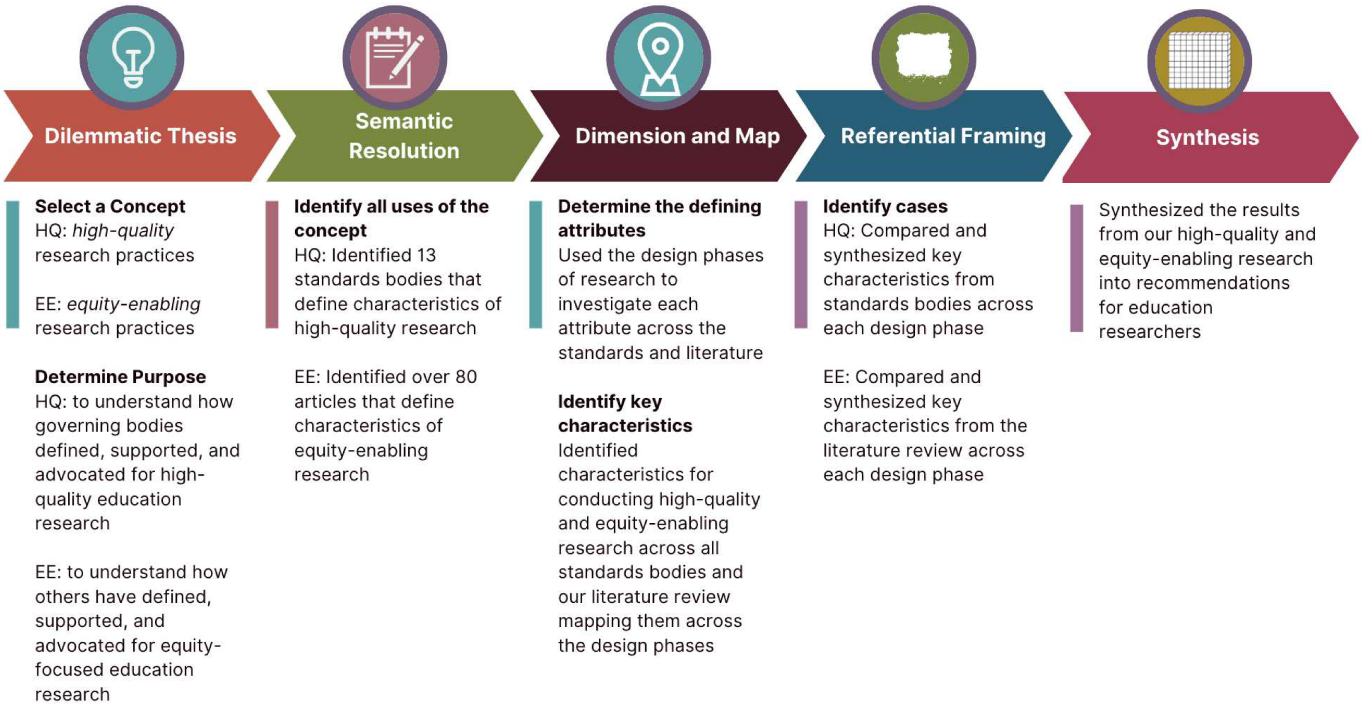

Figure 1: Our research process. While we rely heavily on the framing of Petrina [117] and Walker et al. [157], our needs diverged from their framing in the final steps.

research across all standards and our literature review. A narrative summarising the key elements of each was developed and added to frame our recommendations.

3.4 Referential Framing

Petrina defines referential framing as how the concept is framed or referred to for consumption, everyday use, and understanding. Walker et al. calls for two steps that align with referential framing: 1) identify borderline, related, contrary, invented, and illegitimate cases; and 2) identify antecedents and consequences.

For our investigation of standards, we assessed the relevance of the standards, their content, and their characteristics for high-quality research. We added highlights from each standard into a spreadsheet for further comparison, analysis, and synthesis. Highlights of this work are presented in the Results section, Section 4.

For our investigation of equity-enabling practices in education research, we identified key considerations that arose across each of the research phases through structured searches of the education research literature, including in fields closely related to computing education such as medical, science, and engineering. We then compared, analysed, and synthesised the findings. Results are also presented in the results section, Section 4.

3.5 Representational Provision (Synthesis)

Petrina calls for a representational provision in the next step, which is defined as how to represent, think, or understand otherwise about this concept, and whether a new concept was discovered or developed provisionally. This aligns with Walker et al.'s step to define empirical referents. Here, we synthesise the results of our analysis of characteristics of sound and equity-enabling research. These results are presented in Section 4.

3.6 Researcher Positionality

This working group comprised eight researchers from six countries (Australia, Canada, Finland, India, The Netherlands, United States) with representation of education knowledge from additional countries (Germany, Greece, Nigeria, Romania, Russia, Spain, Italy, United Kingdom). We present some of our backgrounds that influence our study here (as much as we are comfortable sharing). Given that we have eight researchers within this group, we recognise that this only provides a thumbnail sketch without providing more nuanced perspectives of how our backgrounds influence this report.

- One author has been conducting education research for over 15 years, with much of this work focusing on marginalised groups and how to bring stronger evidence into the computing education research body of knowledge. Her perspective recognises that for computing for all to happen, education researchers need to focus their attention on "all". All means equitable outcomes across various learners, and this can be achieved by building the evidence of research across learners. She brings this position into this work, while also recognising that her perspectives are limited to her lived experiences as a White woman in the computing field.

- Another author has been conducting education research for 15 years with a focus on undergraduate software engineering education with a focus on supporting student help-seeking and collaboration. She recognises that her identity as a white woman limits her perspectives.
- Another author has engaged in education and education research with an international background in studies and work across two foreign countries. He acknowledges that he brings limited lived experiences as a white man in the field of computing education that may affect the research process and outcomes. To reduce bias and broaden his perspective, he is proactively seeking diverse input from others and lifelong learning opportunities in equity-focused education and research.
- Another author is a junior faculty member and a newcomer to CS education research, but has spent over fifteen years supporting learners in a variety of educational institutions as a teaching assistant, assistive technology specialist, and faculty, working closely with Disability Services. She has extensive personal experience with education in three countries/cultures, two of those as an immigrant. She is cisgender, asexual, and has ADHD.
- Another author has had over a decade of experience teaching CS in schools and postsecondary institutions, with degrees in education and recently CS. He specialises in K-12 CS education research, with a specific interest in underserved populations and disadvantaged groups. He identifies as a Nigerian Black man and recognises that his perspective influenced his contribution to this work.
- Another author has over ten years of teaching experience at the undergraduate and graduate levels, with degrees in computer science and software engineering. He has a strong background in algorithms, software systems, and optimisation, becoming interested in the computing education research space after participating in their first ITiCSE Working Group back in 2020. He is a tri-lingual, heterosexual, white man from a middle-class family, who is dedicated to improving the computing education experience for all students through his research and lived experiences. He recognized that there are limitations based on this.
- Another author has engaged in computing education research in the last ten years, working with international groups. She is an immigrant whose family has been prosecuted by dictatorial regimes. Her career focus has been on providing educational opportunities for students in underrepresented groups. She identifies as white and middle-aged, and recognises that this will limit her perspective.
- Finally, another author has been a teacher for more than 20 years, with an additional 25 years of experience in the IT industry and public sector. She has specialised in teaching and teacher training in computer science, with experience in disability, special needs, and a current PhD research focus on autism.

To fill in missing knowledge and lived experience gaps in this study, we also invited eight additional researchers to critique the guidelines in more detail. These researchers were limited to various locations within the U.S. and had varying levels of experience in computing education research. Each was invited based on their unique experiences of gender, race/ethnicity, geographical location (including some in states where diversity, equity, and inclusion bans have been put into place for publicly supported efforts), and experiences with equity-focused research. This resulted in an intense amount of feedback that was highly valuable in shaping our final guidelines in this report.

3.7 Processes

As defined in Figure 1, we divided our group into two. Half of our group initially focused on defining methodologically sound characteristics, while the other half performed an extensive literature review of equity considerations when conducting each major step of education research.

To conduct our literature review, we first define the major steps involved in conducting education research [34]. Each researcher then focused on one or more themes based on the steps (e.g. framing a research problem, identifying appropriate literature for the review), defining keywords and searching the literature through Google Scholar, Google, and digital libraries of ACM and IEEE. Keywords were focused on how to conduct equity-enabling research within each step. We then synthesised the results within each theme to form a synthesis of the results.

To advocate for increased quality of education research, various international and national bodies have created research standards to inform relevant education parties about the effectiveness of interventions, practices, and programs. The research standards created by these bodies can inform how to assess methodologically sound CER in the context of countries' priorities and their diverse communities. Table 1 highlights the final subset of the reviewed standards for which we conduct further analysis in our study.

Though we focused on documents written in English, we endeavoured to search high-, middle- and low-income world countries for standards bodies. Our extensive search covered a variety of countries and regions (i.e. India, Africa, Italy, France, Spain, Portugal, Ecuador, Peru, Chile, Argentina, Brazil, Japan, South Korea, United States of America, Canada, Australia, United Kingdom, New Zealand, Austria, Greece, and Germany). While a number of standards documents from different regions were found, very few were sufficiently comprehensive to become part of our review.

After collecting relevant information related to conducting sound and equity-enabling education research, we formed a set of guidelines that took important aspects of each, blending them into a single set of guidelines for each step that researchers can use in the future.

3.8 Standards' Definitions for High-Quality

Overall, the standards focused primarily on characteristics of methodologically sound research (which encompassed essentially the entire documents), while a few had characteristics of equity as well [19, 106, 151]. However, what was lacking were clear definitions for methodologically sound or equity. Although a lack of definition for equity makes a bit more sense, since equity is a term that can be interpreted in many ways, and many formal definitions of it exist, it is nonetheless surprising that more standards have not embraced

Table 1: Evidence standards in education research.

Standards	Organisation	Country	Description
Common Guidelines for Education Research and Development [152]	U.S. Institute for Education Sciences and the National Science Foundation	United States	Defines cross-agency guidelines for improving the quality, coherence, and pace of knowledge development in science, technology, engineering and mathematics (STEM) education.
CONSORT [21]	Self-established working groups from the medical community	International	Defines how to improve the reporting of randomised controlled trials.
Ethical Guidelines for Education Research	British Educational Research Association (BERA) [19]	United Kingdom	Defines guidelines for conducting educational research, including defining methodologically sound research and ethical responsibilities.
Good Research Practice [155]	Swedish Research Council	Sweden	Identifies quality criteria and equity components in research.
Guidelines for Safeguarding Good Research Practice - Code of Conduct [55]	German Research Foundation (DFG)	Germany	Defines standards of good research practice, focusing on defining "high-quality research", discussing what that means with respect to performance, and providing guidelines on professional ethics.
Guidelines on the assessment of contributions to research, training, and mentoring [106]	National Science and Engineering Research Council (NSERC)	Canada	Defines guidelines on the assessment of contributions to research (quality and impact)
Journal Article Reporting Standards (JARS) [7]	American Psychological Association	United States	Defines guidelines for manuscripts on what should be included in quantitative, qualitative, and mixed methods research.
Quality policy [1]	French National Research Agency (ANR)	France	Focuses on funding quality; specifically, the quality of their projects, quality of their service, and ensuring the efficiency of their organisation.
Scottish Educational Research Association Ethical Guidelines for Educational Research [133]	Scottish Educational Research Association (SERA)	United Kingdom	Focuses on ethical code of conducts.
Standards of evidence [12]	Australian Education Research Organisation	Australia	Provides a definition for "rigorous evidence" and how it ensures quality.
Standards for Excellence in Education Research [151]	U.S. Institute for Education Sciences	United States	Defines rigorous education research, with a focus on equity, and the need to make findings, methods, and data open.
What Works Clearinghouse: Procedures and Standards Handbook, Version 5.0 [150]	U.S. Department of Education	United States	Categorises the evidence from individual studies and intervention reports with one of five effectiveness ratings: strong evidence (Tier 1), moderate evidence (Tier 2), promising evidence (Tier 3), uncertain effects, or negative effects.

equity in education research that encompasses the vast diversity of student learners, particularly in K-12.

We found characteristics related to equity in several standards. U.S. Institute for Education Sciences specifies that research needs to 1) discuss how the research defines and operationalises educational equity (e.g. improving learning outcomes, access to resources, opportunities), 2) strive to improve outcome validity and transferability for different groups (especially historically marginalised groups[3]), and 3) design interventions that account for implementation context–consider input from key relevant parties during all stages of the research [151]. The British Educational Research Association standards include researcher responsibilities, such as

[3]We use the term historically marginalised groups to encompass a broad set of groups who have historically been part of minority groups within computing. This includes women as well as Black, Indigenous, and Latinx peoples. This over-arching term is used sparingly throughout this paper.

being mindful of how structural inequalities affect all social relationships and groups; and being sensitive and attentive towards such structural issues at all stages of research, including reporting and publication. Finally, the National Science and Engineering Research Council of Canada [106] describes fair access to research support and equitable participation in the research system.

4 RESULTS OF CONCEPT ANALYSIS

There is no single, one-size-fits-all solution or template that can define or structure a sound, equity-enabling research study. Equity itself is a process that should and will evolve over time [64]. However, based on our findings, we blend characteristics for methodologically sound and equity-enabling education research for computing into guidelines.

In this section we present the results of our literature review of characteristics that define equity-enabling education research. We consider how equity has been defined in the past, how policies and practices incorporate equity, how frameworks are used to measure equity, and how previous findings relate to equity in research design. Since there are different ways to read this report, and we believe some readers will jump straight to the guidelines section, we summarised the previous sections to support the recommendations. Further, while striving for completeness and meeting every single guideline for every project is admirable, it may not always be practical. Those new to education research may also consider the elements that will improve their research and see these as a way to achieve further professional growth.

4.1 Engaging in Researcher Reflexivity

Reflexivity is part of both sound and equity-enabling education research and is "the ability to take account of one's self and the effects of personality or presence of the researcher on the investigation" [120, p. 6], which requires sensitivity to how power relationships operate within the research process [79] and to how it affects the researcher's relationship with, and perspective of, the subject [71]. Researchers should reflect on their background, experience, and knowledge (e.g. cultural values, beliefs, training) in approaching a study, and consider how their prior understanding impacts their research practice [7]. Researchers should be mindful of power differentials inherent in their relationship with study participants and work to protect participants' interests [133].

Owing to the biased nature of human evaluations, researchers' positionality must also be considered. Positionality details the researcher's view of the world *and* the research position they adopt, including its social and political context [72, 131]. Researchers can share their positionality in their publications as a few sentences or a few paragraphs, depending on the nature of the study and, of course, page limitations for the publication venue. This, however, is never a mandate, and researchers must consider their own privacy needs and vulnerability when publicly sharing their positions [87], weighing this against the need to situate the research.

Researchers should also recognise that their experiences, personal values, and the contextual similarities they may or may not share with the participants affect study findings and interpretations, potentially undermining the research [24, 63, 73, 115]. By recognising their limitations, researchers can collaborate with others who have encountered lived experiences similar to the target study population to broaden the knowledge of participants of those on the research team. Irrespective of the participants' diversity dimensions, researchers must refrain from discriminatory language and demonstrate respect in all phases of the study. For studies that require consideration of the influence of an intervention (e.g. experimental, quasi-experimental), effort should be made to lessen the design effects equitably across participants [133].

> **Diversity, equity, and inclusion initiatives in research necessitate diversity, equity and inclusion among the researchers [10, 53], which could be aided by equity-focused researcher networks [32].**

Finally, it is the responsibility of education researchers to 1) prioritise the safety and well-being of both research staff, staff who may be peripherally involved with the research, and participants, especially in situations involving fieldwork or sensitive investigations and 2) ensure that staff (including student staff and volunteers) are not exploited (e.g. asking staff to conduct reviews of papers without credit; asking staff to work long, extended hours beyond a typical 8-hour work day; expecting volunteers to review research paper submissions without reciprocation) [133].

Table 2 provides a summary of this analysis, presented as guidelines for engaging in researcher reflexivity.

4.2 Adhering to Research Ethics

Research ethics contain a blend of methodologically sound and equity-enabling standards; they are, in fact, inseparable. Upholding ethical standards and promoting a supportive and respectful environment are essential for the well-being and development of everyone engaged in the research process. Ethical dilemmas in research can lead to dissent with guidelines, community, and laws, and all of these must be weighed when making research decisions. What we offer in these guidelines is ethics as a starting point, not as the complex topic that all researchers must consider and take into account when choosing their research conduct [146, 158]. Where appropriate in these guidelines, we moved ethics specific to research phases into the relevant sections to keep these items coupled with the research phases. However, remaining here are items related to ethics that did not fit into other sections and more broadly apply to all aspects of research.

Ethical research guidelines define ethics much more directly and all-encompassing [19, 55]. The ethical responsibility of a researcher can be broadly analysed through five perspectives [19], namely for participants; data integrity, privacy, and storage; sponsors, clients, and beneficiaries; publication and dissemination; and well-being and development of researchers and staff. The researcher's responsibilities to the community include considering and responding to concerns and complaints, considering the well-being of the broader community (including other researchers), and refraining from negative and/or aggressive behaviour [19].

Table 2: Guidelines: Engaging in Researcher Reflexivity

Engaging in Researcher Reflexivity
☐ Engage in Self-Reflection
☐ Acknowledge researchers' positionality and its impact on the study, including how it does or does not: mitigate biases, address limitations, impact the data collection process, and impact the interpretation of data. This includes identifying relevant elements of the researcher's background, experience, and knowledge (e.g. their technical expertise and prior experiences with computing), whilst safeguarding their well-being [24]. This includes how prior understanding influences their approach to the study design, including reporting [7].
☐ Engage in reflexivity to consider how the methodological approaches chosen align with the researcher's lived experiences and how these choices and experiences impact their research.
☐ Respect participants' diversity dimensions and avoid using deficit-based framing and discriminatory language across all phases of the study, including research instruments (e.g. existing and new) and reporting.
☐ Reflect on researcher positionalities and recognise researchers' own limitations, expanding the research team as necessary (e.g. by considering diversity dimensions that are historically underrepresented in computing) to fill potential gaps in understanding participants and/or getting additional training [115].
☐ Supporting researcher well-being
☐ Only engage in research in which the researcher can be perceived as not having any conflict of interest outside of research discovery (e.g. financial, reputational). This does not exclude research methodologies like autoethnographic research or other research that the researcher can engage in because of their unique positionality.
☐ Ensure the safety and privacy of research staff and participants (particularly in fieldwork and when investigating sensitive issues). While ethics review boards often focus on the safety and privacy of participants, considering the well-being of research staff should also be intentionally addressed.
☐ Do not exploit other researchers (including students, staff, and volunteers) (e.g. asking staff to conduct reviews of papers without credit; asking staff to work long, extended hours beyond a typical 8-hour work day; expecting volunteers to review research paper submissions without reciprocation).
☐ Respect the well-being of the research community (including individual researchers and reviewers) when engaging in discussions and when receiving and sharing reviews.
☐ Consider community-building through mentoring and support of new researchers and researchers from marginalised communities.
☐ Honour the publication's requirements for who should be included as authors. When authorship requirements prohibit the inclusion of a researcher involved with a study, acknowledge them elsewhere in the publication.
☐ When using prior research data conducted in cooperation with others, ask for consent to use the underlying data and determine appropriate acknowledgement of contributions.

Table 3: Guidelines: Adhering to Research Ethics

Adhering to Research Ethics
☐ Recognise the values of all participants, relevant parties, and the communities to which they belong. As individuals and communities can hold values that are not aligned with equitable practices, researchers must reflect on what it means to engage in research with such participants.
☐ Some communities may choose not to engage in research, or choose not to engage in research with researchers from outside of their communities [140]. Respect their choices.
☐ Develop researcher competency (e.g. qualified to collect and protect data, qualified to choose and use an appropriate methodology).
☐ Develop researcher knowledge and application of research ethics. This includes the researcher as an individual and as belonging to a broader community of researchers where opportunities like sharing knowledge of ethics, engaging in mentoring, and engaging in peer review with an equity-lens can build research ethics knowledge and application throughout the community.
☐ Respond to concerns and complaints as appropriate, including responding to unanticipated problems related to risks to participants or others and complaints. Be aware that complaints and noncompliance may result in suspension or termination of the study.
☐ Comply with laws, regulations, and formal and informal agreements, recognising that these may be "minimal standards" and may even run counter to protecting participants' well-being and safety. Ethics in research typically require a higher standard, particularly when protecting vulnerable participants [55].

4.3 Framing the Research Problem and Questions

Methodological soundness summary: One of the most critical aspects of research design is forming the research problem and corresponding question(s). A research problem is a specific area of concern, an underlying condition that could be improved, or a gap in existing knowledge that can be addressed through research. Researchers may choose to look for practical problems aimed at contributing to change, or theoretical problems aimed at expanding knowledge. It is important that researchers frame and formulate the education problem(s) for the focus area of their study that is derived from the current state of research (i.e. theoretical and empirical underpinnings) [7, 152, 155]. Research problems should consider research scope, context, and limitations, including methods that may be used to explore the research question [55, 152, 155]. This includes explicitly defining populations and interventions [150].

Research questions provide an overarching direction for a study to follow. It guides the type of study, the type of data to be collected, and the type of data analysis to be performed. Writing sound research questions is an important step in framing a study. Research questions should be clear, concise, specific, neutral, and focused. They should also be complex enough that the question requires more than just a yes or no answer, although sometimes a study's purpose may be aimed at such.

When framing research problems and questions, researchers have to consider whether the problem can be adequately explored (Parson, 2019). Specific to computing education, researchers should be aware that hardware and software tools that are used in the study may have their own unintended impacts (e.g. accessibility, costs, data privacy). Further, high-quality research requires taking into account many types of disparities that influence participants, interventions, and research in general. For example, within the United States, it is well known that students who live in areas associated with poverty attend schools where test scores are generally lower than in other schools. Such underlying conditions can influence research outcomes when not taken into account. These underlying conditions must also be considered when framing the research problem, corresponding questions, and, ultimately, choosing the research design.

Research problems and questions are the stepping stones for choosing an appropriate research design, which consists of a cross-section of the many steps offered within these guidelines. To further improve adherence to methodologically sound research practices, researchers may want to register or pre-register their study design on platforms that provide open registration for education research [6]. Pre-registration is a way of describing the research plan, the setting for the research, and the participants prior to starting a study [6]. Any study can be pre-registered and studies are typically pre-registered prior to any form of data sampling. Registration is similar to pre-registration in that it's a detailed plan of how research will be conducted [6]. However, registration takes this a step further with two different stages tied to journal submissions. In Stage 1 the researcher writes the introduction, hypotheses, literature review, methods, and data collection and analysis plan. This manuscript then undergoes peer review, resulting in a journal acceptance or rejection. If accepted, researchers can begin the study and write their final manuscript. In Stage 2, the researchers submit their manuscript to the same journal as Stage 1, so reviewers can assess how closely the researchers followed their proposed plan and how well they detailed and justified any deviations. Of course, not all research efforts allow for sufficient planning ahead so as to allow for such registration practices.

Equity-enabling summary: While there is a dearth of research on how to generate equity-enabling research questions, Fernandez notes that approaching research with an equity focus requires researchers to ask questions that are not traditionally asked and in ways that are not traditionally used (Fernandez, 2019). Research problems and questions should pointedly state how they will investigate equity, inclusion, diversity, and belonging and how they will tackle other disparities within the study.

Accessing and maintaining access to education research sites and participants can also be challenging for any study, especially when working with marginalised groups; however, navigating this problem early in the research design phase can help ensure that research can be completed. Maintaining access will require sensitivity to the ethical precepts of each group and the context of the study [8].

Research problems and questions should clearly state how they will investigate equity, inclusion, diversity, accessibility, and belonging, or how they will tackle other disparities within the study and/or within computing education. Research problems and questions should honour and respect the lived experiences of the populations included in the study. The framing and questions should be asset-based rather than deficit-based (as defined in the section Identifying a Critical Framework, in 4.4). Researchers should acknowledge their own power, biases, limitations, positionality, impacts on and harms to communities, and threats to validity.

Inviting included populations to co-design research, participate in data analysis, or participate in the interpretation of the analysis can mitigate some of these issues. For example, research-practice partnerships (RPPs) provide an opportunity to bring together practitioners and researchers to collaboratively address a problem of practice [26]. Framing research questions in a manner that is inclusive of marginalised communities is a useful exercise for advancing equity-based research. For example, data on disability status is often not collected but could be useful to others in the community due to a lack of knowledge about how best to teach computing education to them. Certain methodologies can be leveraged to include educators in the research process. For example, action research is a collaborative, iterative, and situationally responsive research method most commonly used in educational settings, dedicated to simultaneously investigating and resolving issues identified by the participants, making it well suited for investigating equitable approaches in STEM [15, 27]. Including students as participant-researchers can allow for a better understanding of students' lived experiences and for embedding their views within the research, while also reducing the negative effects of power dynamics between the researcher and the students as well as observer biases [20].

Furthermore, equity-enabling research extends beyond generating knowledge; it seeks to foster positive change by reducing disparities and promoting inclusivity. Researchers should be mindful of the impact and outcomes of their work, striving to contribute

to a more equitable society. This may involve advocating for policy changes, implementing interventions, or developing educational materials that are designed with equity and inclusivity in mind.

Above all, researchers have an ethical responsibility to engage in practices that do not further marginalise or harm already underrepresented populations. This includes conducting research that is sensitive to the needs and perspectives of marginalised groups, actively seeking their input and participation, and using the research process as a tool for empowerment and positive change.

In the context of training "highly qualified personnel", it is crucial to incorporate diversity, equity, inclusion, and accessibility principles into the training of future researchers, including fostering a research environment which follows these practices. This includes teaching researchers how to craft research questions that address or reflect equity concerns, providing them with the methodological tools to conduct inclusive research, and instilling in them the ethical responsibility to prioritise equity and inclusivity in their work.

Table 4 defines the integrated guidelines.

4.4 Identifying a Critical Framework

Methodological soundness summary: Where appropriate, clear *conceptual* and/or *theoretical* frameworks can serve as the foundation for a study, offering a basis that facilitates discussions on complex, diverse, and interrelated issues [151]. Theory also guides methodological decisions and informs action. At its heart, theory gives structure to and thus facilitates a deeper understanding of data and relationships. Methodologically sound theories are supported by data and remain largely consistent in the face of small contextual differences among multiple samples. They beget specific, testable hypotheses about how things interact and explain observed patterns [46]. Further, methodologically sound theories present clear definitions of the theorised constructs, which helps facilitate communication and shared understanding among researchers. Researchers should engage with theory, either as a foundation, or a subject of critique, in shaping and/or contextualising their questions and arguments [81].

When a framework cannot be found that meets the needs of the study, broadening the search to fields that intersect with general or STEM education may yield frameworks that have been vetted in previous studies. Education research is rich with various learning theories and frameworks that computing education can build upon. If current theories are inadequate, ill-suited, problematic, or dehumanising, it may be more appropriate to offer new theoretical ideas or develop grounded theories. For example, researchers have engaged with work on neurodiversity within computing education, but pushback from some reviewers has demanded the use of ableist theories, limiting the scope to dominant strands of frameworks, thus threatening possible publication [81].

Equity-enabling summary: Assumptions may be embedded within the research design that may result in the omission of participants' valuable lived experiences [23]. Adopting critical framing for conducting equity-centred educational research is vital for identifying and addressing systemic inequities in computing education research [119, 145], cultivating a social justice/equity orientation, and meaningfully contextualising the data. An equity-enabling framing requires rejecting and abandoning oppressive epistemic ideas about knowledge, and may enable the researcher to situate a study more inclusively and prevent generating assumptions about participants. For example, the inclusive framework (InCrit) was designed for classroom use, observing relationships between theory, practice and examples [37].

A few frameworks relevant to methodologically sound, equity-enabling research include funds of knowledge, asset-based approaches, intersectionality, and the CAPE framework. The concept of *funds of knowledge* was derived in the early 1990s by González et al. who conducted a study along the U.S.-Mexico border with minoritised and underprivileged families [59]. The authors described funds of knowledge as "historically accumulated and culturally developed bodies of knowledge and skills essential for households or individual functioning and well-being" [59, p. 133]. In the field of engineering, Verdin et al. discuss how stereotypical perceptions of engineers create a non-inclusive culture [154]. In the context of computing, when researchers' assumptions about computing students' knowledge and backgrounds are embedded into the research design, they risk missing truths about lived experiences [23]. By acknowledging and tapping into the funds of knowledge, the researcher situates their study more inclusively [105, 154]. Through increased awareness of the implications of funds of knowledge, researchers can identify expertise within a community as well as recognise what constitutes knowledge in the context of the study and the participants, supporting the well-being, self-efficacy, and agency of the participants' communities [59]. This may include interpretive frameworks that are well-suited for minoritized populations, such as Black Feminist Thought by Collins [28] or co-design methods that promote more equitable research, such as Research Practice Partnerships and other practices that invite participants to be part, in essence, of the research team [54, 107].

Historically, deficit thinking has been used to frame gaps in academic achievement. Often referred to as an *integrationist approach*, this thinking frames education ecosystems as culturally neutral and students need to accommodate ecosystems that were not built for them. This thinking does not see schools as having the responsibility to shape their ecosystems to accommodate all students [56]. Further, deficit thinking tends to blame the oppressed for their own oppression, leading to the erroneous use of students' identities as the reasons for their failures (e.g. the fallacy that women can't code [115]). Documenting what students *cannot* do and their achievement gaps can increase marginalisation and reinforce negative social constructs [53]. Deficit thinking has been particularly harmful for students with disabilities. Much of the neurodevelopment research presents a bleak and ablest view of neurodevelopment disorders based on a medical "deficit" model [18, 52]. The language used in equity research to refer to and describe students with disabilities and other minoritised students must be replaced with a framework that reflects an asset orientation [14].

Documenting what students *cannot* do and their achievement gaps can increase marginalisation and reinforce negative social constructs [53].

Table 4: Guidelines: Framing the Research Problem and Question(s)

Framing the Research Problem and Question(s)
☐ Clearly formulate and frame the research problems and questions, considering scope and context, as follows: ☐ Current state of research (i.e. theoretical and empirical underpinnings) [55] ☐ Define the problem, the phenomena being studied, the unit of analysis, the social context, and how the researchers either designed the context or gained access to it [81]. This may include defining the selection process and access to participants [152]. ☐ Define how equity, inclusion, diversity, belonging, and disparities will be explored ☐ Ability to answer the question in the available time and with available tools and other resources ☐ Frame problems and questions as asset-based rather than deficit-based (see Section 4.4). ☐ Honour and respect the lived experiences of the included populations. ☐ Choose hardware and software tools for an intervention that are accessible to and protective of the included populations (such as students with disabilities and other vulnerable populations). ☐ Acknowledge limitations, positionality, impacts on and harms to communities, and threats to validity. ☐ Invite included populations to co-design the research and research questions.

To prevent research from adopting a limited perspective, it is also essential to address complex intersectionalities [58]. Coined in the 1990s, intersectionality is rooted in Black feminism. It recognises and values the subjectivity of marginalised experiences and the interconnectedness of marginalised groups. The term *intersectionality* describes an intersection or combination of differences in minoritized identities [31]. Intersectionality of gender, race, ethnicity, socioeconomic status, and other socio-cultural groupings can present obstacles that inhibit a student from pursuing computing. Existing narrow perceptions of one's computing identity and a lack of a sense of belonging form a barrier for minoritized students [122]. Addressing identities that intersect with disability is particularly important to avoid taking a narrow perspective on disability [58].

The CAPE framework offers a way to evaluate equity in computing education by focusing on four fundamental aspects of equity: Capacity, Access, Participation, and Experience (as shown in Figure 2 [51]. Research studies adopting CAPE have explored the experiences of women of colour [51], race/ethnicity, gender, socio-economic background, urban/rural and geographic location [159]; gender and socio-economic background [98].

QuantCrit, which is aligned with critical race theory and social justice, describes a holistic research approach that uses quantitative data to improve conditions for minoritised groups, observing differences in perspectives and over time [164]. Critical race theory challenges deficit-based perspectives on race to give a fuller, more accurate, and more representative picture than traditional approaches, which risk showing bias against racial and ethnic groups [115].

Table 5 defines the integrated guidelines.

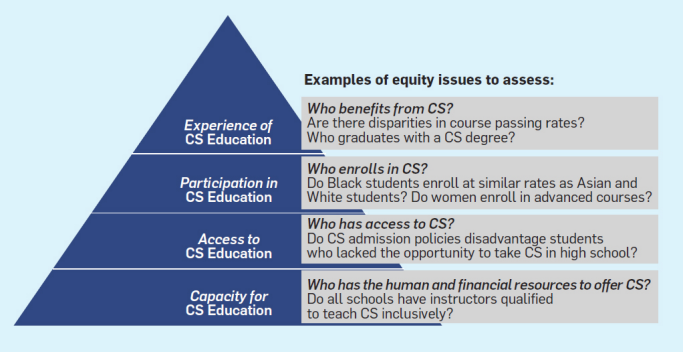

Figure 2: Capacity, access, participation, and experience (CAPE) framework for equity inquiry in computing education. [51]

4.5 Conducting the Literature Review

Methodological soundness summary: Reviewing academic literature is critical in developing a deep understanding of a research topic, becoming familiar with it, identifying knowledge gaps, and informing research design. To achieve these ends, a literature review should discuss connections between previous studies, experience reports, books, products, services, other media, and current research through a critical lens [7]. Reviews of academic literature need to follow a structured and consistent approach. Sound literature reviews go beyond simply listing top-line findings from previous studies; they present an integrated discussion of the literature as a whole, identify and highlight points of convergence and divergence among similar studies, and clearly articulate why the topic under study is important not only for the researchers but also for the general public. Literature reviews can take many forms [62], and thus the quality of each review is determined by slightly different criteria specific to each form (e.g. systematic vs. scoping vs. meta-analytic reviews).

Equity-enabling summary: Reviewing academic literature through an equity lens encourages meaningful contextualisation of the findings and their implications. Publications that address biases and are more inclusive can have a greater impact, as they produce insights that are relevant and meaningful to a broader population and to diverse communities. For example, the term professionalism has been used to justify further marginalisation of Black people

Table 5: Guidelines: Identifying a Critical Framework

Identifying a Critical Framework
☐ Adopt a critical framework, i.e. critically and equitably contextualise the research
☐ Employ diversity dimensions that most equitably serve the research and the affected communities
☐ Delineate asset-based diversity dimensions (e.g. race, ethnicity, gender, disability)
☐ Consider discretising commonly used categories and metrics into smaller, more inclusive, and more descriptive categorisations and evaluations.
☐ Identify similarities and differences within and across the studied/impacted groups.
☐ Identify intersectionality and any complexities inherent to the overlapping contexts of the participants and their data.
☐ Identify and honour funds of knowledge from who has expertise in this context (area, community, socio-political climate, etc.), considering:
☐ what is considered knowledge in this context?
☐ what are the assets of the participants and their communities?
☐ what are the equity-focused needs and the desired outcomes?
☐ Identify and use equity-centering metrics, tools, and procedures

(especially Black women) [125]. Thus, search terms could unintentionally exclude a set of people within a community. For literature reviews on some population groups where limited research may be available, expanding the search beyond traditional publication venues to include blogs, newspaper articles, and technical reports can prove fruitful as previous research has shown that authors from marginalised groups have faced exclusionary practices in publishing [102, 106]. Systemic publishing practices that marginalise researchers can be mitigated by engaging in citational justice practices that "...uplift marginalized voices with the knowledge that citation is used as a form of power in a patriarchal society based on white supremacy" [148]. This may include seeking out and citing research articles from women and other marginalised groups in computing that investigate learning from non-dominant groups' experiences [3, 84, 148].

When reviewing publications, consider the explicit and implicit power dynamics (including conflicts of interest) between and among researchers and participants. Applying an equity lens when reviewing research includes consideration of the study's limitations as well as its context. By critically examining academic literature, researchers can find limitations that may serve as entry points for further research–or, at a minimum, may serve as a reminder to treat the results with healthy scepticism. This practice can ensure that new studies are inclusive and equitable.

Table 6 provides a set of guidelines for reviewing the literature.

4.6 Choosing Research Methods

Quantitative data can offer great insight into observed phenomena, including generalising results to broader populations, finding patterns and averages, and finding correlations and causation. However, quantitative often groups data into predetermined categories, which can have a de-contextualising, shoehorning effect, ultimately focusing on the what and how many. On the other hand, qualitative analysis seeks to identify core themes and meanings in the data, allowing for contextualisation, ultimately discussing the why and the how [101]. However, qualitative analysis does not lend itself to broader generalisations. Both can provide valuable insights separately or combined. A post-positivist view often presumes data neutrality, leading to the fallacy of quantitative method superiority [22, 91, 94, 99, 115]. In fact, the "superiority" of one method over another is determined only by the research question being asked–the method chosen must align with the question under investigation. Misalignment between research questions and methodology can result in unanswered research questions at best, or incorrect conclusions at worst.

4.6.1 Quantitative Methods. **Methodological soundness summary:** Quantitative research design must be anchored in appropriate existing methods, while new approaches must focus on quality assurance and establishing standards [55]. Several types of quantitative research designs are common in educational research (e.g. descriptive, randomised controlled trial, quasi-experimental, correlational, time-series, longitudinal, single-case design), and each serves a distinct purpose. Researchers should, before data collection, determine the desired sample size (informed by the expected effect size associated with the relationship under study), which type of effect will be measured (e.g. differences in means, correlations, regression coefficients), materials and measures to be used, procedures to be used, and data sources [7]. The validity of the researchers' use of all common metrics should be reassessed with respect to the research questions and participants [55]. For example, a measure of self-efficacy ought to be used only to investigate self-efficacy and not some unrelated construct. Further, measures used should have sufficient psychometric quality (e.g. high reliability, adequate factor structure). Continually evaluate what and how data is used to ensure alignment with the research questions and participants based on new knowledge gained throughout the study [53].

Equity-enabling summary: Quantitative methods within a post-positivist epistemology often fail to acknowledge researcher positionality and the effect it has on data interpretation [63, 165].

Table 6: Guideline: Conducting the Literature Review

Conducting the Literature Review
☐ Conducting the Search
☐ Identify search terms using inclusive criteria and keywords. This includes awareness of their situational contexts and usage, including contexts that have been connected with the exclusion and oppression of individuals.
☐ Include studies published in journals and conference proceedings that are reflective of the population groups that are included in the planned study. If necessary, consider blogs or other publicly available media when working with minoritised populations.
☐ Assessing for inclusion and exclusion
☐ Follow a structured and consistent approach for reviewing the literature.
☐ Evaluate and connect related work to the planned study through a critical lens.
☐ Consider the historical and cultural context in which the studies being reviewed are situated.

Further, while commonly collected individual demographic variables allow for comparing outcomes across social groups, failing to appropriately frame these variables misses crucial causal mechanisms driving observed inequalities [115]. This lack of proper contextualisation leads to negative perceptions, biases, deficit-based interpretations of the data [164, 165], and, ultimately, to policies that reinforce inequality by prioritising changing students instead of changing environments [22, 94, 99, 115].

While overcoming dominant-group norming is challenging, accounting for context, discussing positionality, and acknowledging limitations can improve quantitative studies [24, 53, 74, 112]. The validity of all metrics should be reassessed with respect to the research questions and participants [53]. Further, missing crucial contextualization results in flawed data interpretations that reinforce systemic inequalities [63, 115, 164, 165].

Recommended minimum sample sizes can differ depending on the population size, standard error of measurements, expected effect sizes, and alpha level chosen [2, 83]. Smaller sample sizes can often yield larger effect sizes than larger samples, but observed effect sizes are influenced by observed variance in the data, and variance in the data can become extremely large or small given small sample sizes. Thus, smaller sample studies may be less generalizable [138], but the generalizability of any study should ultimately be judged in light of methodological decisions/rigour and how representative the sample is of the target population. To evaluate the effects of an intervention or program, researchers prefer randomised-controlled studies, but well-designed quasi-experimental studies can often suffice [138]. As some programs are most commonly evaluated in small studies, while others in large, there is a potentially misleading distribution of observed effect sizes when considering meta-analysis, which can be addressed by weighting effects by study sample size or their variances, log transformations, or square roots [138].

Advanced statistical models (e.g. multilevel models) better account for data contextualisation by incorporating data clustering (i.e. dependence among similar observations) within educational settings that then can be individually compared for equitable outcomes [47, 85, 88, 109]. Researchers can also disaggregate monolithic data categorisations, empowering participants to describe themselves more meaningfully and inclusively [16]. When using quantitative data, equity can be furthered by privileging the experiences and desired outcomes of non-dominant communities [53] and focusing on asset-based approaches [115].

4.6.2 Qualitative Methods. **Methodological soundness summary:** Like quantitative methods, qualitative methods are informed by the study context and the approaches to inquiry (e.g. descriptive, interpretive, critical, feminist, constructivist) and may evolve over the course of the study. Like quantitative studies, qualitative studies are judged on their methods. One key difference, however, is in qualitative studies the researcher often is the data collection instrument, rather than a survey or checklist. Relatedly, while quantitative studies rely on statistical analyses, the researcher often is the analysis mechanism in qualitative studies. While you might sum or average scores on a survey measure in a quantitative study, you will often rely on the researcher to make meaning of written text, audio, or artefacts in qualitative studies. While quantitative data are judged by their reliability and validity, qualitative data are instead judged by their credibility and transferability [33, 35].

Fully describing the rationale for the study design and how it addresses the research question(s) bolsters the transparency and credibility of the study. This can be addressed by describing the researcher's impact on the data collection and analysis processes [7] and using appropriate detail to describe the processes, especially when data is collected and/or analysed across multiple researchers [86]. Qualitative data can be presented quantitatively (e.g. intercoder reliability) or qualitatively (e.g. postmodernist approach that values representation across all researchers [9]), though care should be taken when understanding and overstating the value of the quantification of qualitative results [66]. There is no expected minimum number of participants for qualitative research, but a detailed rationale should be provided for the number and nature of participants selected [7]. One recommendation in qualitative research that uses inductive coding is that sufficient sample size has been achieved when you reach "saturation" in the data [33, 127]. Saturation occurs when no new information (operationalized differently in each study) is uncovered with additional participants.

Continually reflecting on researcher positionality across all stages of qualitative research can help minimise the effect of biases. Claims may be supported through supplemental checks such as member checking, external audits, and triangulation [7, 34].

Equity-enabling summary: Qualitative research recognises the researcher as an instrument, whose positioning must be explained alongside other contextualising parameters and settings [93, 113]. Qualitative research methods enable understanding of the lived experiences of participants in a particular context, recognising the complex and occasionally contradictory nature of human experiences, which is invaluable for education research [93]. Qualitative research methods are especially important for understanding the experiences of participants from groups historically marginalised in computing education, since their experiences may not be captured in quantitative research given that they often present as statistical outliers. Further, unique and information-rich data collected from participants can contribute to a deeper understanding of phenomena in computing education. As mentioned above, researcher positionality may impact data collection and analysis and requires management [7]. Qualitative data is particularly valuable for equity-focused research because it can unveil underlying facets of injustice and bring to light the interlinked aspects of different types of oppression [30].

Qualitative approaches are also uniquely well suited for informal learning spaces without standardised assessments, where participants can instead provide contextualised qualitative data [42]. Nevertheless, there is a shortage of qualitative CER [29, 68], especially for specific minoritized groups. One potential reason for a deficit of qualitative studies is the misconception that small participant sample sizes cannot contribute to knowledge, despite the insights that can be gleaned from in-depth studies of small groups [93] and the preponderance of qualitative studies even within the medical research field.

4.6.3 Mixed Methods. **Methodological soundness summary:** Mixed methods research leverages both quantitative and qualitative approaches to data collection and analysis to provide a multifaceted investigation of research phenomena. The central philosophy of mixed-methods research is that it uniquely generates insights about phenomena that are otherwise impossible to obtain with just quantitative or qualitative approaches alone. In other words, mixed-methods research is more than just the sum of its parts; in mixed-methods research, 1+1=3 [50].

Central to mixed-methods research is the concept of integration [36, 76]. Integration refers to how the researcher combines aspects of quantitative and qualitative inquiry to generate insights that are otherwise impossible to obtain with either methodology alone. Integration can occur at one or multiple "levels" of the study (i.e. Purpose, Research Question, Design, Method, Results, and Discussion). Combining qualitative and quantitative methods can provide insights that go beyond those provided by one methodology alone [89]. It is essential to specify in which phases each methodology is used and how they are combined, illustrate how the research design aligns with research questions, and convey the intent behind the mixed methods approach. Best practice involves integrating the findings from all methods to address the research questions and objectives, whilst acknowledging the limitations of doing so. [36] outline three core mixed methods designs (Convergent, Explanatory sequential, Exploratory sequential) and each core design has several variants. The primary difference among the three core designs is when the researcher uses quantitative vs. qualitative methods in the course of the overarching mixed methods study. Mixed methods research should not be confused with multiple methods research. Multiple methods research, for example, may use multiple qualitative approaches (e.g. using systematic literature review, interviews, observation) that inform each other [123].

Equity-enabling summary: Combining a variety of complementary methods can enhance the understanding of the variables and their relationships, making mixed methods a powerful option for education research [93, 115]. Mixed methods research captures complex and information-rich data and provides opportunities for in-depth understanding, which can inform more inclusive and effective practices. Mixed approaches allow researchers and policy-makers to synthesise both qualitative and quantitative findings for systematic literature reviews [114]. There is greater potential for creating unique opportunities for engaging diverse beneficiaries throughout the research process, which is particularly important when examining inequities and exploring ways to support marginalised groups.

4.6.4 Methods Guidelines. Table 7 presents an overview of the guidelines related to quantitative, qualitative, and mixed methods.

4.7 Engaging with Participants

Methodological soundness summary: When considering participants, people, communities, or organisations, it is important to clearly explain procedures and context and how choices about who may be involved in the study are necessary to answer the research question(s). This enables researchers to clearly understand how the research engaged with participants and their communities [7, 19, 132, 150]. Clarity about procedures and context also aids replicability, particularly when providing details about inclusion/exclusion criteria, sample size and reasoning (including discussion of the expected effect size), procedures for recruitment, assignment to conditions (e.g. random, group similarities), and procedures for engaging participants in the research. At a basic level, cultural sensitivities regarding participant agency and their ability to choose whether to participate should be prioritised, so provide opt-out and withdrawal options. Study procedures should be informed by ethical considerations for human subject research, including consent, consideration for vulnerable populations, and power dynamics, with strategies in place to mitigate researcher biases [19].

When conducting computing education research (CER), it is crucial to acknowledge K-12 students are a vulnerable population due to their limited autonomy [67]. Study participants should be aware of their rights and of the nature of the study[43]. Since studies in K-12 education include minors, researchers must know when informed consent (from caregivers/legal guardians) and assent (from participants under 18) is needed from the participants and/or their caregivers. For this reason, research communities that focus on children and youth in educational contexts often require authors to include sections that address ethical considerations regarding participant recruitment and participation, data collection, and sharing among other aspects [153]. Researchers must obtain consent in accordance with local laws and regulations from participants and locations (including institutions) where the study will take

Table 7: Guidelines: Choosing Methods

Choosing Methods
☐ Determine appropriate methods; if new methods need to be created for the study, clearly state why known methods are not appropriate and clearly state the process for creating the new method.
☐ Define the research design, sample size, materials, measures, procedures, data sources, and the study type, selecting appropriate methods of inquiry to answer the research question(s) [7]. For quantitative methods, this includes descriptive, randomised controlled trial, quasi-experimental, correlational, time-series, longitudinal, or single-case designs and variants of each. For qualitative methods, this means study types may include ethnographic, grounded theory, phenomenology, or ethnography. For mixed methods, this includes convergent, explanatory sequential, and exploratory sequential designs and researchers should clearly plan which phases of the research project will use quantitative and qualitative methodologies [34, 89].
☐ Privilege the experiences and needs of non-dominant communities, centering asset-based approaches.
☐ Acknowledge researchers' positionality and its impact on the study, including how it mitigates biases, addresses limitations, impacts the data collection process, and affects data interpretation.
☐ Collect and continually assess evidence of validity and reliability. For quantitative data, this may mean conducting analysis using Cronbach's alpha, confirmatory factor analysis, and exploratory factor analysis. For qualitative data, this may mean engaging in member checking, external audits, and triangulation.
☐ Develop consistent data collection and analysis techniques when multiple researchers are engaged in collecting and analysing qualitative data.
☐ Disaggregate monolithic groupings for more contextualised and inclusive characteristics (e.g. collecting diversity dimensions that accurately reflect the participants, comparing groups using descriptive and inferential statistics (e.g. multilevel models)) [16, 137].
☐ Acknowledge all changes to the procedures, including inconsistencies or deviations, as well as their potential impact on findings.
☐ Ensure the data adequately captures all relevant forms of diversity, adapting to arising needs for more or different data when needed for representation.
☐ Mixed methods
☐ Clearly communicate the purpose, intent, and rationale behind using a mixed methods approach, including how methodologies complement each other in addressing the research questions and objectives.
☐ Qualitative methods used in a mixed-methods study should meet the criteria for qualitative methods.
☐ Quantitative methods used in a mixed-methods study should meet the criteria for quantitative methods.
☐ Integrate findings from the quantitative and qualitative methods, investigating the meaning behind complementary and contradictory data.
☐ Reflect upon any challenges, biases, and trade-offs from integrating findings and provide a transparent account of how these limitations will be mitigated or managed.

place (Scottish Educational Research Association, 2005). Special consideration should be given to protected (vulnerable) groups, with particular attention to Indigenous peoples. Consent must also be acquired from participants to use their data for research outside of its original intended purposes as stated in their original consent form. It is crucial to be mindful of the power dynamics between researchers and participants (e.g. teacher/student relationships), including the use of incentives (Scottish Educational Research Association, 2005). Harms may accrue to participants or related groups; for example, some survey questions may trigger trauma based on participants' lived experiences. As a researcher, being aware and sensitive to potential harms and mitigating them in advance can protect participants (Scottish Educational Research Association, 2005). There are some situations where legal and/or ethical obligations may require a researcher to disclose information about participants to others; participants should be informed in advance about any such possible situations. Collecting and reporting the grade level and age group of student participants is important to understand the setting of the research. Reporting both is necessary to draw international comparisons, especially since computing education in K-12 continues to emerge and the limited research is shared internationally to gain greater understanding [97]. Since grade levels differ across different countries, researchers should specify the grade level with the age group of the students, so data can be meaningfully compared.

Equity-enabling summary: As noted by UK Department of Health, researchers need to respect diversity and recognise the many cultures within society [147]. To equitably represent diverse groups, it is critical to consider underrepresented communities during all research phases, from design to distribution of findings [10]. A crucial step is to disaggregate monolithic categories into subgroups whose needs are currently concealed within larger categories, while also accounting for complex intersectional identities [163] (and further discussed in the Methods section). To this end, deliberately sampling participants to account for their many differences and complex intersectionalities will produce research that reflects society.

Participatory equity frames equity as dynamic, since it may change from one social interaction to the next [136]. While purposeful sampling of information-rich cases is common [113], the research focus might not include balancing for representation, retention of diverse participants, or reporting on diversities when distributing findings [137].

Since failures to identify and mitigate recruitment/retention challenges can result in unrepresentative samples, it is crucial to consider a wide variety of participant motivations and opportunity costs, sampling rationale, and recruitment successes and failures [70, 78, 111]. These challenges are exacerbated when working with historically marginalised populations, where population groups may be very small and motivations for participating are critical to ensure representation of their views.

Diversity dimensions should be considered for context in data analysis and reporting as well as part of answering the research questions(s) to maximise transparency(Natural Sciences and Engineering Research Council of Canada, 2022; American Psychological Association, 2021). These dimensions include gender, race, ethnicity, age, disability, sexual orientation, geographic location, language, socio-economic status, mental and physical health, neurodiversity, and other aspects of diversity (Natural Sciences and Engineering Research Council of Canada, 2022).

Considering intersectional identities [137], disaggregating monolithic groups [163], and exploring how equity may change across interactions are all part of equity-enabling research [106]. [20, 136]. Importantly, equity may change across contexts; in one context, the researcher may be more powerful, while in another a participant may be. Relatedly, power dynamics between participants may change. Where possible, researchers can engage in research-practice partnerships or similar types of partnerships which cultivate long-term partnerships with individuals or entities to engage in research at all levels, including framing the research and providing access to particular participants, resources, opportunities, or information [8].

Appropriately categorising and disaggregating participants based on their identities can enable understanding of the nature and complexity of various groups of learners and help prevent further disadvantaging them [163]. It is also essential to avoid making assumptions about category groupings as they are largely dynamic and subject to change through time, between cultures, and perceptions of self-identity. For example, if the views that women "just don't like computing" persist over time, advocating for change will be very challenging. Further, broad terms like *underrepresented minorities* and *historically marginalised groups* often group many individuals into an over-represented majority, giving way to ethnic heterogeneity [16]. There are often more stringent ethical considerations in research with participants that are considered vulnerable [39], including those with disabilities, neuro-developmental disorders, learning disorders, prisoners, students, and similar groups.

Disabilities. Research on students with disabilities remains understudied in computing education, with between 2% and 5% of articles reporting student participants' disability statuses since 2017 [149]. In the United States, 15% of students receive services for special education needs [103], which indicates that research on disability is lacking and there is an opportunity for researchers to learn more about how students with disabilities learn computing [17]. Furthermore, the prevalence of autistic persons in STEM and computing careers is increasingly acknowledged [61, 143], highlighting the need for further research in this area. While collecting this data can be challenging, local or regional education terminology may be a starting point for determining the types of categories that may provide insight into the data.

Race and ethnicity. Generalisations across race and ethnicity are too frequently made, diminishing the specificity, relevance, and value of the collected data. For example, "Asian Americans" in the U.S. census is a classification for people from the Far East, Southwest Asia, and India, as well as Native Hawaiian or Pacific Islanders [163]. In India, there are 705 officially recognised ethnic groups, yet all people from India are placed in the same category as people from Taiwan, despite clear socio-political, cultural, linguistic, and economic differences. This categorization leads to a monolithic representation that does not accurately depict racial, ethnic, or social realities.

Cultural identity. Cultural identity can include language, social group, religious tradition, economic status, gender, age and sexual orientation [108]. The body of CER should reflect this diversity in learners who are included in studies to inform and guide practitioners and policymakers [5, 147]. This can be achieved by ensuring all researchers are aware of the importance of considering diversity, equity, and inclusion in their research. Researchers should identify the points where teacher and student backgrounds do and do not align, and their analysis should explore whether this (non-)alignment impacted outcomes. Determining accurate categories will provide a deeper understanding of various groups of learners and their specific needs.

Gender. Given that only one in four positions in the tech industry are held by women [104], it is important to understand why this phenomenon exists and what interventions may show promise in ensuring girls do not encounter environments where they are made to feel like they do not belong in computing. However, only two-thirds (64%) of papers collected data about student gender [95], and the vast majority of this data examined gender through a binary lens. Given that broader self-identifying terms have emerged over the last few years, there is a need to collect data that accurately reflects non-binary representation of gender.

Emerging language learners. How researchers frame students who speak a different language than the one used in the classroom can shape how researchers view the students and how the findings are interpreted. Using an asset-based approach, terms that reflect students' existing language skills, such as emerging bilingual/multilingual and English fluent students [75] can be used. At present, only 22% of the papers in the K-12 CS Education Research Resource Center dataset (n = 196) specified whether student participants were emerging bilingual learners.

Educator identities. Teacher identities can impact the way minoritised students learn [100] and thus should be considered when working with them as participants or staff delivering instruction to students. However, Sleeter's literature review on teacher education in the U.S. found that research has historically focused on the experiences and lack of knowledge of White preservice teachers [139].

Montecinos notes that when data "...are not desegregated by ethnicity readers are implicitly led to believe that the participants'

ethnicity is irrelevant when examining the possible impact of multicultural course content" [100, p. 173], which ignores the body of evidence that indicates that teacher identities influence students' academic achievement and their beliefs. Further, research on instructor identities is minimal (although increasing), as instructor race is still rarely reported: in 2014, 2015, and 2016, no studies collected this data, while 17% did in 2022 [95]. Teachers' previous experiences of learning and teaching computing can influence students' academic achievement and should therefore be collected and reported, to provide context to the students' learning experiences.

Table 8 presents an overview of the guidelines related to participants.

4.8 Crafting Instrumentation and Collecting Data

Methodological soundness summary: Researchers must consider methods, including the quality, validity, and reliability of those methods, used to collect, transform, and analyse the data [7, 55]. Data, storage, protection, and privacy principles and practices must be easily understandable for participants. For studies that collect data, the instruments and protocols developed and used should have evidence of reliability and validity, be up-to-date, and, where possible, be supported by literature [55, 151]. Research studies could also adhere to the ethic of minimal burden[4], minimising the workload and inconvenience of participants and seeking only questions that are directly related to the research question(s) at hand (Scottish Educational Research Association, 2005), unless the participants are involved in a study that engages them in research (e.g. action research [141]).

Additionally, when obtaining data to answer a research question, when possible, the findings (typically in the form of a report) should be made available to participants [151]. When choosing hardware and software tools for data collection, these tools may have their own unintended impacts (e.g. accessibility, costs, data privacy) and should be chosen with care.

Equity-enabling summary: The ways in which data is collected for research studies need to be culturally relevant and fit the situational context. To better reflect racial and ethnic identities, Viano and Baker recommend that self-reports serve as the main source of data collection in studies [156]. Similarly, research conducted in contexts that support both quantitative and qualitative data collection measures (e.g. open-response questions) has the potential to broaden the knowledge base and provide a more thorough, accurate, and richer understanding [24, 53]. Self-reported qualitative measures are valued, but they can also be more challenging to analyse and/or aggregate. Awareness of this may influence instrumentation design.

Collecting evidence of validity and reliability of existing instruments in new and different contexts is essential [40]. Validity determines whether an instrument is measuring what it is intended to measure. Reliability measures the consistency of an instrument in similar contexts [40]. Evidence for validity and reliability should take into account minoritized identities and situational contexts to help ensure that data analysis generates accurate inferences [53].

Demographic data must also be collected with care [142], attending to how items are worded and how they may be perceived by different participants. For example, gender as a binary selection erases many people, and putting "other" as an option for gender is detrimental to the participant. Phrasing it as "not listed" or "self-describe" can provide more nuance to collected data and help reflect participants more accurately. Further, only asking for data that is central to answering the research questions should be standard practice, which emphasises the importance of research questions that capture the included populations in some way. Finally, when possible, allow free-form responses, which provide the ability for participants to self-identify. When not possible (or in combination with this), Strunk and Hoover suggest phrasing "If you had to choose one of the following options, which one most closely matches your [identity]?", accompanied by a multiple options [142, p. 169]. Viano and Baker also stress the importance of considering factors such as country of origin, race/ethnicity, and language. Prior experiences (particularly with computing education) are also an important point of data to collect, since prior experiences can influence future learning outcomes [156].

Data collection should indicate how participants were informed of why their participation is necessary, including what information is required of them and how the information will be processed and reported [19]. Participants need to be informed about the retention, sharing, and any secondary use of their data [19], and there should be transparent explanations of how participants' data was de-identified to ensure the confidentiality of the data [106, 133, 155]. Researchers should also provide ways for participants to easily withdraw consent for their data to be stored and used where appropriate or possible. Researchers' use of incentives to encourage participation must show good judgement (e.g. being too little or too much, offering incentives that might conflict with the values of the participants) Scottish Educational Research Association, 2005). Considerations regarding data sensitivity, original purpose, and intended audience should be taken into account when creating instrumentation, norming assessments, or using secondary or tertiary data [19]. Researchers should adhere to local laws and their institution's best practices, which may include external ethics review for the collection, use, and protection of research participants and their data [133, 151]. Researchers should also ensure that constructs are equivalent across cultures and languages. This can be addressed by asking researchers or community members with similar backgrounds to the anticipated participants to review the instrumentation prior to administering it, and then using the feedback to improve the instrumentation.

Finally, data privacy and security are essential considerations. Online survey software may collect data that may be commercialised, which could lead to further marginalisation of groups and even individuals. Further, the tools used must reflect the context and the culture for the study [53]. Audio and video recordings can be particularly sensitive, and ensuring that recordings have no identifiable information associated with them can protect participants, but full masking of voice and appearance can be difficult to achieve. At a minimum, asking participants to change their on-screen name to a pseudonym in the recording can help protect their identity.

[4]In some countries, this is referred to as *minimal intrusion*. However, countries use this phrase in different ways, and therefore we have chosen to use the phrase *minimal burden*.

Table 8: Guidelines: Engaging with Participants.

Engaging with Participants
☐ Selecting participants
☐ Clearly define the procedures and context for participants in the research study.
☐ Choose and enlist participants from all relevant groups, taking into account factors such as sample size, power analysis, and appropriate representation.
☐ Specify inclusion/exclusion criteria, sample size rationale (when it fits into the study design), recruitment and retention procedures, assignment to conditions, and participant follow-up during and, where appropriate, after the study [7, 19, 132, 151].
☐ Identify how the criteria for choosing participants will answer the research questions(s), particularly from an equity-enabling perspective.
☐ Define diversity dimensions as appropriate for the research question(s) and context to maximise transferability of findings [7, 106].
☐ Provide opportunities for participants to share their own identities (e.g. gender, race/ethnicity) as appropriate for the research [110].
☐ Cultivate relationships to broaden understanding of and access to sites/participants, improving quality, equity, generalizability, and transferability [8].
☐ Interacting ethically
☐ Ensure ethics for human subject research informs procedures, including consent and consideration for vulnerable populations (e.g. Indigenous peoples) [7]. This may include obtaining caregiver consent for all minors, consent/assent from participants, and consent to use publicly accessible data for research purposes where appropriate.
☐ Honour participant choice and withdrawal from the study. Anticipate and mitigate potential harms to participants or related groups.
☐ Inform study participants (including, where appropriate, caregivers for minors) of their rights, the nature of the study, and their role in it with awareness of cultural sensitivities [7].
☐ Considering power dynamics
☐ Be aware of and, when possible, mitigate power dynamics between researchers and participants (e.g. teacher/student relationships) [133].
☐ Share data results and analysis with participants to ensure that the research is appropriately representing them.
☐ When possible and where needed (e.g. deception studies), provide participant debriefing of the study. Similarly, provide opportunities for participants to give feedback, particularly on hardware and software tools used in the study.

Generally, data storage also must be considered and who has access to the data must be limited to the maximum extent possible.

4.9 Analysing and Interpreting Data

Methodological soundness summary: Beyond design and implementation, researchers need to carry forward their reflections into how they analyse and interpret data, including their positionality, biases, and shortcomings [7]. To improve the analysis and reporting of results, the American Psychology Association (APA), American Educational Research Association (AERA), What Works Clearinghouse (WWC), and the CONsolidated Standards of Reporting Trials (CONSORT) have produced standards that can be applied, including statistical analysis and interpretation of results [96]. The standards note that it is critical to minimise biases when analysing and interpreting data [55], and researchers can broaden their viewpoint and consider different perspectives when interpreting and analysing data. This can potentially help them identify errors in their analysis [155] and ensure the clarity and adequacy of their results. Researchers should clearly define outcome constructs and choose measures, avoid overly aligned measures (e.g. measures that unfairly advantage a treatment group over a control group), and prioritise theoretical or practical significance for educators and decision-makers.

Aligning the interpretation of results with the research questions and study benefits and study harms, combined with other relevant evidence, clarifies the implications of the study [132]. For quantitative analyses, researchers should check and report the results of all assumptions relevant to their particular statistical analysis and report decisions made about outliers identified. Researchers should consider the limitations of their analysis, even if this compromises the initial ambitions of their research studies [155].

Equity-enabling summary: As noted by Strunk and Hoover, data is neither neutral nor objective. For quantitative data analysis, the statistical procedures (e.g. regression, correlations, structural equation models) should be properly executed and researchers should reject the idea that results and/or patterns observed through these statistical measures are fully objective because they are quantitative. Pearson et al. suggest that when analysing and interpreting data, education researchers should take a more holistic approach that considers context and power dynamics instead of focusing exclusively on the academic performance of marginalised students.

Table 9: Guidelines: Crafting Instrumentation and Collecting Data

Crafting Instrumentation and Collecting Data
☐ Respect participants' diversity dimensions and lived experiences, and avoid using deficit-based framing and discriminatory language when collecting data from participants.
☐ Check to see if instruments with evidence of validity or reliability already exist that may suit the needs before embarking on creating new instruments. When using existing instruments, however, consider the words that were used to collect diversity dimension data and whether inappropriate language or framings have been used. When using or updating any instrument, this may create a new need to collect evidence of reliability and validity.
☐ Consider data sensitivity, original purpose, and intended audience when using secondary or tertiary data.
☐ Consider how hardware and software tools for data collection may have unintended impacts (e.g. accessibility, costs, data privacy).
☐ Use good judgement when incentivising participants to partake in the study (e.g. being too little or too much, offering incentives that might conflict with the values of the participants) [133].
☐ Adhere to local laws and ethics review boards, as well as the ethic of minimal burden when appropriate to the research methodology.
☐ Integrity and data privacy and storage
☐ Create and follow policies and procedures for data collection, storage, use, disclosure, protection, and privacy (including allowing for participants to withdraw consent of their data where appropriate or possible and declare any incentives used during the data collection process).
☐ Make evident how the participants' privacy is protected, including data de-identification procedures and information regarding who will have access to the data [106, 133, 155].
☐ Be accountable, and hold others accountable, for the ethical acquisition and use of data
☐ Comply with applicable statutes, regulations, practices, and ethical standards governing data collection and reporting.
☐ Take all possible steps to protect the confidentiality and anonymity of participant data.
☐ Keep data secure by limiting who has access and ensuring data protections are put into place and followed.

Strunk and Hoover further suggest approaching the data and analyses more reflexively, considering that statistical errors may be anomalies that represent an individual's lived experiences, and ensuring the interpretation of the data reflects the communities from which it was collected. Data analysis techniques are informed by the context of the study, the situational contexts of participants, and the power dynamics between and among researchers, participants, and their communities Pearson et al.. Results that challenge previous findings or expectations do not necessarily indicate invalid results. Results may be related to several factors, including the self-reported lived experiences of participants [142, 155]. Considering diversity dimensions and participants' lived experiences improves understanding of research outcomes for different groups [55, 151].

Equitable interpretations of both quantitative and qualitative data require awareness of how various forms of culture shape and may be shaped by our research [80]. Asset-based interpretations of non-dominant communities [53, 115] are aided by researchers' commonalities with the participants [73]. Thus, equity initiatives need researchers who are representative of the communities studied [10, 53]. By reflecting on their own experiences, researchers can conduct research in a more respectful and asset-based manner [115], leveraging collaborations with other researchers who may share experiences with the participants [32].

4.10 Reporting on Research

Methodological soundness summary: The standards that address reporting emphasise the importance of rigorous and ethical research reporting practices [7, 12, 19, 132, 133, 151, 152, 155]. The standards recommend detailed description and interpretation of both quantitative and qualitative findings, comparisons to related work, implications, limitations, and potential for future research. Standards also highlight the importance of transparency through data provenance, support for replications, and provision of information required for review and assessment. They also emphasise the need for making data transparent (including null and inconclusive findings), making datasets and source code publicly available and ensuring proper citations.

Protecting the confidentiality and the anonymity of participants in reporting is critical; however, de-identified data can sometimes be triangulated, which can lead to the identification of participants [32]. Recent research has highlighted the potential risk of using new tools to de-identify participants [13, 90, 121]. This means that researchers must exercise caution when choosing to use publicly available archival storage repositories and ensure that consent has been provided by the participants to share data publicly. If researchers intend to share data for secondary analysis, they should ensure that the data is thoroughly cleaned, de-identified, and reviewed by a second researcher before sharing.

Ethical considerations demand accurate reporting of results, disclosure of funding, acknowledgement of incentives, a careful reflection of participants' views and experiences, a consideration of the interests of communities impacted by the research, and avoiding sensationalising findings. The research should be published in the languages of the audience (e.g. publication venue, impacted communities whenever practical), provide free access to the work whenever possible and practical [19], and accurately describe the

Table 10: Guidelines: Analysing and Interpreting Data

Analysing and Interpreting data
☐ Ensure that the research methods used are adequate for addressing the study research questions, while also considering their limitations and the impact of available tools on addressing the research questions.
☐ Assess relevant assumptions of each statistical analysis performed, and modify interpretations of results accordingly, if necessary.
☐ Consider study context, power dynamics, and situational contexts to inform the selection of data analysis techniques [115].
☐ Ensure the interpretation matches the results of the study and assess benefits and harms that might occur while considering additional supporting evidence and crucial information [132].
☐ Utilise diversity dimensions when evaluating results to understand the impact on different groups [55, 151]. Consider alternative viewpoints or the individual's experience when results do not match expectations.
☐ Seek collaboration with diverse colleagues and study participants, and continuously reflect to limit biases and ensure a more reliable interpretation of results.

research goals, research questions, design, implementation, data, and findings. If researchers intend to share data for secondary analysis, they should ensure that the data is thoroughly cleaned and de-identified, with a second researcher examining the data for identifiable information before its release.

The situational context impacts the interpretation of the study results [55] and forgoing the historical, political, and social structures that influence the participants or ecosystems to which they belong can misrepresent study findings. The reported results should be contextualised by: addressing the research questions/hypotheses; connecting the results to related work; providing an interpretation of the results; describing generalizability or scope of transferability; describing the work's implications, contributions, and significance; clarifying the limitations; and describing ethical dilemmas and challenges [7, 19, 132, 133].

Equity-enabling summary: Since data is not neutral and interpretation of data can be used to reinforce stereotypes and biases, reports must centre equity to situate the study within historical, cultural, socio-political, and geographical contexts [60]. This practice includes using vocabulary that honours participants' experiences and their communities. Including the voices of participants through quotations in the report can provide important insight into their perspectives. Thus, it is essential that researchers report findings in ways that honour the participants and their lived experiences, rather than using their data to reinforce patterns that favour dominant groups [144]

Defining equity and describing how it is operationalized orients the readers to the influences that it had throughout the study. Demographic factors such as socio-economic background and race are often not reported in CER [97], leading to research findings that lack transparency of whom the research actually reflects. Procedures for participant recruitment and retention are also often omitted from reporting, despite being a vital and challenging aspect of conducting research [78, 137]. If, for example, the research is focused on an intervention related to an elective computing education course, there will be a selection process that may limit who is engaged in the study. Who participates in the study (e.g. experience levels with CS, students from families with high-income status) may influence the findings, making it important to acknowledge who participated and why they were included.

Additionally, a statement of the researcher's positionality is crucial when reporting on research studies [112]. Researchers can increase the value of a study's findings by reporting diversity dimensions [97], researcher positionality [112], procedures for recruitment and retention [78, 137], and plans for sharing findings with the impacted communities.

5 DISCUSSION

5.1 Cementing the Equity and High Quality Narrative

While there are various perspectives that portend that introducing equity degrades quality, our research strongly suggests and the evidence supports that methodologically sound and equity are inextricably linked [150]. Having one without the other jeopardises not only the researchers' ability to identify promising practices in computing education, but also the ability of administrators and decision-makers to bring them to scale to meet the needs of all learners. The move from local usage to wide-spread scaling of promising practices is resource- and cost-intensive.

There are currently over 2 billion children aged 0 to 14 [160] in the world who deserve to have the opportunity to learn computing. Treating them as a monolith will ensure dominant-norming practices are those that are adopted, leaving behind critical opportunities to deliver computing education in the most impactful ways possible and that guarantee equitable outcomes. High-quality CER must include an equity lens for its findings to support research that may be applicable to the CER community and, in particular, may be needed to fill gaps in education research among marginalised communities. Conversely, for equity-enabling research to provide the evidence needed for decision-makers and educators to make decisions that contribute to the delivery of an equitable education ecosystem, it is critical that it is performed to the highest standards of quality.

Equity-enabling CER that also meets methodological standards should be infused into the research community as a clearly articulated and promoted standard. This includes creating awareness and recognition that what the CER community does (or does not

Table 11: Guidelines: Reporting on Research

Reporting on Research
☐ Describing the research framing and question(s)
☐ State the research problems and questions
☐ Define equity and related terms and explain how they were operationalized in the research.
☐ Describe the current state of research (i.e. theoretical and empirical underpinnings) [55].
☐ Define the problem, the phenomena being studied, the unit of analysis, social context, and how the researchers either designed the context or gained access to it [81].
☐ Describe how equity, inclusion, diversity, belonging, and disparities will be explored.
☐ Frame problems and questions as asset-based rather than deficit-based.
☐ Describe the hardware and software tools for an intervention that are accessible to and protective of the included populations (e.g. students with disabilities, other vulnerable populations).
☐ Describe the positionality of the researchers and how this impacted the choices made during research (reflexivity).
☐ Describing methodologies
☐ Describe the study design used, including how it was implemented in the research.
☐ Describe all relevant aspects of the research process including the ethical review process, consent process and rates, participant interaction, data privacy and storage, and incentives.
☐ Describe the data collection instrument(s) and method(s), including quality and reliability metrics.
☐ Describe the data analysis methods used.
☐ Describing participants
☐ Include diversity dimensions, recruitment and retention numbers, and researcher positionality [78, 97, 112, 137], ensuring that the report states the identities of participants or communities in the way they want to be defined.
☐ Define the selection process and access to participants [152].
☐ Protect confidentiality and the anonymity of participants in reporting. De-identified data can sometimes be triangulated, which can lead to the identification of participants. Exercise caution when choosing to use publicly available archival storage repositories and ensure that consent has been provided by the participants to share data publicly.
☐ Report incentives provided to recipients.
☐ Reporting on findings
☐ Strive for unbiased reporting, including reporting negative results.
☐ Provide detailed descriptions and equity-focused interpretation of the results. Avoid selective reporting of contexts, results, and findings, since even null findings are important to know.
☐ Highlight comparisons to related work, implications, limitations (including threats to validity), and potential for future research and practice. Acknowledge limitations, impacts on and harms to communities, and threats to validity.
☐ Reporting on conflicts of interest and sources of support
☐ Acknowledge sponsors, clients, and relevant parties in publications.
☐ Report conflicts of interest.
☐ Formatting reports
☐ Write the report in a manner and style that suits the reader for whom it was intended. For example, use academic language for publications meant for researchers to read and use more practice-based language when writing publications for practitioners.
☐ Ensure that the publication is accessible to people with disabilities.
☐ Selecting publication venues
☐ Where possible, publish in open-access venues in the languages of the publication venues and impacted communities.
☐ Carefully weigh the risks of publishing source and/or participant data, keeping in mind that data de-identification techniques continue to evolve [13, 90, 121]. When data risk is minimal and participants have consented to their data being shared publicly, submit research data to permanent, publicly-available archival storage repositories.

do) may negatively impact children whose lived experiences may be vastly different from those experienced by researchers. Those negative impacts may impact the future quality of life of children, including further marginalisation of children and their communities, missed opportunities for future financial stability, and missed opportunities for understanding how current and future technologies may impact them.

> **Equity-enabling computing education research that also meets methodological standards should be infused into the CER community as a clearly articulated and promoted standard.**

5.2 General Observations

Our conceptual analysis identified standards that provide insight, guidance, and examples for CER. It covers various aspects that can influence how methodologically sound and equity-enabling research is perceived within a research group or community, depending on the group's familiarity with a given standard. For example, ethical considerations might not be well understood within a community with an in-depth familiarity only of WWC [150]. Our study aims to address this gap by providing holistic guidelines informed by best practices across various standards and enabling researchers from different countries and regions to choose the most appropriate ones for their context.

We identified gaps in the discussion of ethics in most of the standards. While there are a few instances that imply ethical consideration in the standards, those that are fully used in education like WWC [150], SERA [133], and Australian Education Research Organisation [12] barely emphasise ethics and its implication for research. The derived guidelines from our conceptual analysis serve as a valuable resource for conducting sound, equity-centred CER. First, they enable researchers to design, implement, analyse, and report on findings in more equitable ways that reduce unintentional harm and exploitation of vulnerable populations such as children and youth. Additionally, they enable researchers to address bias and consider diverse perspectives, making their studies more representative and, therefore, enhancing the objectivity and robustness of their findings. Such guidelines are also practical tools for individuals navigating and critically reflecting on academic literature, as well as reviewing and assessing CER, ultimately contributing to producing equity-focused high-quality research.

Another important point to note is that the well-being of researchers and the community was only considered by a single standard [19], and only with regard to ensuring that researchers behave appropriately within the education research community. This and other aspects of well-being should be addressed more frequently as a dynamic part of a research community.

5.3 Limitations

Our work has several limitations, namely, related to the standard selection and the proposed recommendations. Firstly, despite many members of the working group speaking multiple languages, the standards we selected were in English, since this was the language that the working group used throughout the project. Thus excluding standards that were published in other languages, in some cases from countries with extensive education traditions such as Spain, Italy, and China. In addition, all standards on our list were from high-income nations, as shown in Figure 3. Thus, there is a risk that this work presents an affluent, western, English-speaking perspective.

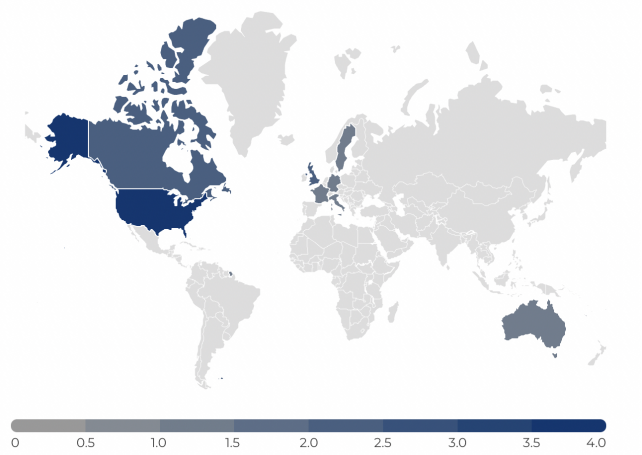

Figure 3: Distribution of Standards across the World

Secondly, our proposed guidelines are distillations from various selected research standards, so it is possible that some are presented in insufficient detail or lack sufficient context. Testing and vetting these proposed guidelines and collecting evidence of their validity and reliability is part of our future work. The selected standards focus on hypothesis-based research over design research, so our current guidelines may lack information specific to support design research.

In our feedback from additional researchers in the broader CER community, the researchers would like to see 1) more examples throughout to provide more clarity and 2) resources for how to engage in research that meets the guidelines. While we are aware of limited space to do so in this paper, our planned, online guidelines will provide ample space to do both. We will also engage in a series of workshops to share the guidelines and processes for achieving them.

Finally, we emphasise that these guidelines are just that–guides to assist education researchers in drawing their attention to simultaneously conducting methodologically sound and equity-enabling research. As we shared this with other researchers for review, the reviewers found areas in our guidelines that were missing, such as our positionality statements and occasional sentences that could be interpreted as deficit-based. One reviewer also found a lack of key citations from education researchers from historically marginalised groups. Though we have worked to mitigate some of these issues, we recognise that equity-focused research requires an ongoing reminder to be constantly vigilant across all aspects of research.

6 CONCLUSION

Our evaluation of research standards and practices led to the identification of the important characteristics of methodologically sound and equity-enabling research. One key outcome is that sound and equity-enabling research expectations are intertwined, both contributing to research being considered high-quality. Additionally, we have clarified definitions of methodologically sound and equity-enabling research in computing. We have identified guidelines for researchers to consider when creating equitable research studies,

including a checklist to support the development and execution of sound, equity-enabling CER studies.

Future work will consider validation of the checklists through extensive interviews with experts in conducting equity-focused research. We will also share these findings on a website and through a series of workshops scheduled over the next year.

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A GLOSSARY

Asset-based. Appreciating and mobilising individual and community talents, skills, and assets rather than focusing on problems and needs.

Citation justice. Defined as the "...act of citing authors based on identity to uplift marginalized voices with the knowledge that citation is used as a form of power in a patriarchal society based on white supremacy." [148].

Deficit-based. A focus on quantifying and qualifying the absence of quality attributes, which results in negative narratives for communities already subject to stigmatisation. A deficit-based discourse has the potential to contribute to the stereotyping and marginalisation of vulnerable communities in wider society.

Diversity dimensions. Various characteristics that have been historically used to differentiate groups, such as ethnicity, gender, religious beliefs, or socio-economic status.

Diversity, Equity, and Inclusion. To distinguish the differences, consider diversity as a fact, inclusion as respecting that fact in the systems, and equity as respecting that fact by dismantling and rebuilding systems [82].

Equity-enabling education research. Research that provides the evidence needed for decision-makers and educators to engage in capacity building by advocating for, supporting, and delivering education that leads to equitable access, participation, and experiences among all students [51]. Equity-enabling education research, by its very nature and necessity, must meet quality standards to provide meaningful evidence.

Methodologically sound education research. Education research that meets technical quality standards. Quality standards may be specific to a publication venue or established standards for an association or organisation.

Intersectionality. The interconnected nature of social categorisations such as race, class, and gender, as they apply to a given individual or group, and which are regarded as creating overlapping and interdependent systems of discrimination or disadvantage.

Minimal burden. Highlights the need for researchers to consider the 'bureaucratic burden' of much research, including the time and resources needed for participants to participate in a study [133]. The goal of minimal burden is to minimise the impact of research on the normal working patterns and workloads of participants. (While some countries may refer to this as minimal intrusion, other countries view the term minimal intrusion as meaning how participants may interact with the research. Therefore, we have used the term minimal burden instead.)

Power dynamics. The way different people or different groups of people interact with each other and influence each other's behaviours, when one of the sides is more powerful than the other. It involves the ability of individuals or groups to exert influence, make decisions, control resources, and shape the outcomes of a situation.

Process, method, methodology. Research methods are procedures for collecting and analysing data. These include qualitative, quantitative and mixed methods; primary versus secondary data collection; and descriptive versus experimental research. Methodology is the specific process used within the chosen method (e.g. cross-sectional survey, ethnography, grounded theory).

Reliability. Instruments with evidence of reliability yield the same results each time they are administered.

Researcher positionality. Refers to the position a researcher has chosen to adopt within a given research study [131].

Situational context. Refers to the historical, geographical, social, religious, economic, cultural, political and environmental conditions at a specific time. Adding the adjective "situational" may help centre the researcher's focus on the situations that participants experience in their lives.

Validity. Research protocols (e.g. instruments, interview questions) with evidence of validity indicating that they measure what they are supposed to measure.