A review of grounded theory-mixed methods analysis and potential application to forensic science education research and practice

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Abstract: Grounded theory has been used in qualitative research for over sixty years and in many subject areas. It has allowed researchers to "ground" their theory in data that is systematically gathered, sampled, coded, categorized, and analyzed. Within science technology, engineering, and mathematics (STEM) education, programs focused on forensic science may benefit from grounded theory mixed methods research that assesses program design, content delivery, student experiences, faculty demographics, and allocated resources. This study set out to identify and characterize current peer reviewed articles in grounded theory mixed methods research in STEM education. A literature search using PubMed (US National Library of Medicine, National Institutes of Health, Bethesda, MD, USA) and Google Scholar (Mountain View, CA, USA) was conducted to identify relevant peer-reviewed articles using the search terms "grounded theory", "research", "science", "technology", "engineering", "mathematics", "education", "graduate", "undergraduate", "educational standards", and "STEM". Research from the past decade (range 2011-2021) was targeted for both graduate and undergraduate education. Using these key terms and search parameters, 165 results in Google Scholar and 20 in PubMed were identified. However, after a closer examination, only 37 and 16, respectively, of the articles were relevant to grounded theory mixed method analysis in higher education research (n=53). Using the identified articles in educational research and practice revealed a total of 52 themes that occurred in at least two or more journal articles. The most studied themes were "applied practice" (18 items), "culture/environments/community/climate/socio-cognitive" (17 items), "communication/handoffs/interpersonal skills" (14 items), "pedagogy" (13 items), "knowledge building/acquisition/learning theory" (12 items), "resources (education and research)" (11 items), and "innovation" (11 items). This review highlights numerous educational research themes or key topics that may help us understand and improve educational outcomes in STEM higher education including forensic science. It is essential that future forensic scientists obtain a level of academic/technical competence, communication/interpersonal skills, protective mechanisms, adaptive skills, professional attitudes, and ethical judgment. These themes should be evaluated with a focus on forensic science to enhance the education students receive and the skills they start out with in their careers.

Keywords (Audience): educators, academics, undergraduate, graduate, postgraduate
Keywords (Domain): grounded theory, mixed methods, education research, forensic science education
Keywords (Pedagogy): synchronous, asynchronous, traditional, hybrid, on-line
Key Words (Topics): grounded theory in education, forensic education, educational standards, education best practices, pedagogy

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Introduction

Educational research is essential to develop best practices, identify and further investigate deficiencies in current approaches, and ultimately improve student outcomes. Within STEM education, programs focused on forensic science may benefit from research that assesses the role educational standards play in program design and content delivery, student experiences, faculty demographics, allocated resources, and more. Historically, grounded theory, developed by Glaser and Straus, has been used in qualitative research for over sixty years and in many subject areas (1). It has allowed researchers to "ground" their theory in data that is systematically gathered, sampled, coded, categorized, and analyzed. Further, Charmaz, Thornberg and other researchers have explored grounded theory and note that it can aid in the development of strategies for theoretical analyses, in the generation of new concepts, contribute to the larger body of scientific knowledge, as well as help to guide policy development and practices (2-5). In the work of Taber, who explored case studies of grounded theory and research in science education, they found "grounded theory approach claims to produce testable outcomes…..and is intended to lead to predictions which may be subject to traditional experimental and statistical testing"(6). We noted in our previous work that forensic science education is relatively new in comparison to other STEM disciplines as is its content delivery via non-traditional, on-line or hybrid academic programs (7). We found that published research on forensic science education effectiveness is limited (8-12). Forensic science has been characterized as a hands-on career, with various sub disciplines including seven overarching scientific areas: biology, digital multimedia, medicine, scene examination, physics/pattern interpretation, and chemistry (13). Each of these forensic disciplines utilizes hands-on techniques whether in the field or in the laboratory. Since 1977, several reviews of forensic educational programs have been published that highlight the variability in academic programs, course work, faculty demographics, laboratory courses offered, as well as the perspectives on hiring decisions regarding forensic science degrees (8-12). Further, with the creation of the Forensic Science Education Programs Accreditation Commission (FEPAC) there has been a shift from unaccredited to accredited forensic programs with the adoption and implementation of meeting accreditation standards (14).

Educational research utilizing grounded theory mixed methods analysis, whether focused on forensic science or not, could help guide future research on the effectiveness of forensic science education. Therefore, this study set out to identify and characterize current peer reviewed articles in grounded theory mixed methods research in STEM education regardless of pedagogy.

Methods

A literature search using PubMed (US National Library of Medicine, National Institutes of Health, Bethesda, MD, USA) and Google Scholar (Mountain View, CA, USA) was conducted to identify relevant peer-reviewed articles. The search terms "grounded theory", "research", "science", "technology", "engineering", "education", "mathematics", "graduate", "undergraduate", "educational standards", and "STEM" were used to identify research in this area. Research from the past decade (range 2011-2021) was targeted for both graduate and undergraduate education. Using these key terms and search parameters, 165 results in Google Scholar and 20 in PubMed were identified. However, after a closer examination, only 37 and 16 of the articles, respectively, were relevant to grounded theory mixed method analysis in higher education research (n=53). Each of the articles were assessed for targeted educational research related to general and STEM higher education research/practice. The selection, screening, eligibility, exclusion, and inclusion process can be viewed in **FIGURE 1**.

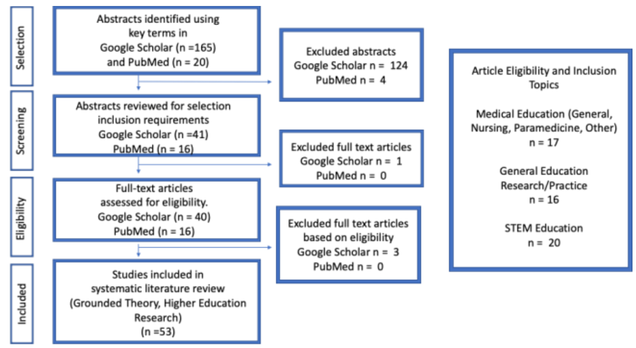

FIGURE 1 Peer-reviewed article selection, screening, eligibility, exclusion, and inclusion process (15).

Results and Discussion

Themes Identified

Using the published research on grounded theory mixed method analysis in educational research and practice revealed a total of 52 themes or thematic groups that occurred in at least two or more journal articles (**TABLE 1**). The most studied themes identified were "applied practice" (18 items), "culture/environments/community/ climate/socio-cognitive" (17 items), "communication/ handoffs/interpersonal skills" (14 items), "pedagogy" (13 items), "knowledge building/acquisition/learning theory" (12 items), "resources (education and research)" (11 items), and "innovation" (11 items). "Mixed methods" (13 items) was also a theme that was specifically identified in the article selection process, in addition to qualitative and quantitative analyses which is often used interchangeably with mixed methods.

TABLE 1 *Identified themes in grounded theory mixed-methods research.*

Themes	Occurance	Themes	Occurance
Applied Practice	18	Modeling	6
Culture/Environments/ Community/Climate/Socio-Cognitive	17	Interdisciplinary	6
Communication/Handoffs/Interpresonal Skills	14	Evidence Based/Social Emotional Learning	5
Mixed Methods	13	Learners Interest	5
Pedagogy	13	Productivity	5
Knowledge Building/Acquisition/Learning Theory	12	Process Influence	4
Resources (Education and Research)	11	Ethical	4
Innovation	11	Resilience	4
Data/Frequencey of Information/Information Processing	10	Preparedness/Transition	4
Academic/Curriculum	10	Collaboration	4
Peer-Peer Interaction/Tutoring	9	Professional	4
Competence	9	Gaps	4
Quality/Best Practices/Standards/Policy	9	Internship/Simulation/Scenario	4
Student Experience	9	Utility of Information	3
Assessment	9	Translational Science	3
Change Research	8	Variability	3
Motivation	8	Implementation	3
Development	8	Self Directed Learning	3
Challenges/Barriers/Corruption	8	Objectives	2
Perceptions	7	Decision Making	2
Adaptive Skills	7	Diversity	2
Evaluation	6	Post-training Work Experience	2
Engagement/Interactive	6	Mentoring/Student Faculty Interactions	2
Student Support	6	Acceptance	2
Interventions	6	Gender	2

In addition to those listed in **TABLE 1**, other themes identified but limited to one occurrence included "accountability", "continuity", "disengagement", "faculty development", "flexibility", "immersive", "indifference", "problem-based learning", "promote", "relevance", "structure", and "service". These topics may not have been studied using grounded theory and/or mixed methodologies extensively, but some, if not all, may warrant further exploration. Although there were over 50 identified themes, some were combined into thematic groups due to topic similarity (i.e., culture, environment, community, climate, data, resources, etc.) and/or targeted behavior (i.e., communication, interpersonal skills, learning/knowledge, etc.). Further, multiple themes or thematic groups may occur in a single article.

Applied Practice and Laboratory-Based Instruction

Laboratory based instruction, applied practice, and hands on skill acquisition, are key elements of scientific education, regardless of the discipline. Grounded theory and/or mixed methodologies have been used to evaluate effective themes in laboratory instruction (16-23). Communication has been found to be essential in learning and group collaboration. Peer to peer learning has been studied and found to be "crucial to students' knowledge acquisition through lab work" (24-25). A theme that not only arises in grounded theory research on laboratory instruction, but other educational research, is culture and how it can influence individual productivity, affect motivations, and facilitate, as well as possibly impede, progress in full student participation (26-31). The application of forensic science theoretical knowledge in applied practice and/or laboratory settings is essential. Indeed, FEPAC standards state that "FEPAC acknowledges that laboratory-based instruction is integral to any science-based discipline such as forensic science" (14). Emphasis is placed on resource allocation to program laboratories, including equipment and supplies, and must demonstrate that the program is able to meet the standard for accreditation (14). The standard shows preference to faculty members with working experience in forensic organizations and the program must interact with local forensic science laboratories.

Culture/Environments/Community/Climate

As previously noted, culture/environments/ community/climate can influence an individuals' ability to become fully participating laboratory members. Organizational climate, culture, community, and environments were the second most common theme group identified (17 items) (26-27, 29-32). Researchers found that the structure of the laboratory and effective communication can "influence group collaboration and individual learning" (30). Peer to peer interaction and collaboration has been found to influence knowledge acquisition. Culture can influence individual motivation, productivity, communication, educational interventions, collaboration, applied practice, and create as well as break down barriers (28-30). In 2009, the United States Department of Justice released the report "Strengthening Forensic Science in the United States: A Path Forward" and highlighted culture in several sections (33). The report stated that "It [forensic science] must have a culture that is strongly rooted in science, with strong ties to the national research and teaching communities, including federal laboratories" and that "This culture leads to continued reexamination of past research and hence increased knowledge" (33).

Communication, Handoffs, and Interpersonal Skills

As important as culture is communication, handoffs, and interpersonal skills (14 items) (20, 30, 34-36). A handoff, in terms of medicine, is important for patient care, where key information is communicated from one practitioner to another that is essential for the quality of medical outcomes (37). Miscommunication due to ineffective handoffs may result in harm to patients. This review identified that communication influences group collaboration, self-directed learning, and facilitates collaboration (20,23, 26, 34, 36, 38-39). Communication can occur in innovative ways such as with the use of social media to facilitate peer interaction (40). Peer-peer interaction can be an important factor in education, especially knowledge acquisition through laboratory practice (30). Further, effective student faculty interaction can have "implications for achieving mastery of core competencies" (39). With regard to effective handoffs in medicine, students need to "learn key information, be open to guidance, apply clinical knowledge, be concise, incorporate delivery strategies, and be open to styles/preferences of handoff recipients" (41). Handoffs, although not often characterized as such, occur in other areas including forensic science. Ineffective communication both within and outside forensic organizations such as through expert testimony can have severe consequences on the outcome of a criminal case. Further, information that is "handed off" to a forensic analyst may result in cognitive bias (42). In forensic science, providing and reserving information that could influence forensic evidence analysis, also known as linear sequential unmasking, is an approach that attempts to reduce bias through withholding task-irrelevant information (i.e., race, gender, etc.) from the forensic scientist until the analysis of evidence is complete (43-44).

Pedagogy, Knowledge Building/Acquisition, Innovation and Learning Theory

The method and practice of teaching, or pedagogy (13 items), is a theme intertwined with knowledge building/acquisition and learning theory (12 items). Further, it is important to understand the effectiveness of innovation (11 items) in knowledge acquisition and transfer through other themes such as assessment (9 items), development (8 items), challenges/barriers/corruption (8 items), students' adaptive skills (7 items), and evaluation (6 items) and their effects on acquiring new knowledge and techniques. This literature review revealed several studies on innovative approaches such as machine learning, augmented/virtual reality, modeling, social media, gamification, simulation-based medical education, maker movement, and massive open online courses (35, 45). Several learning theories have been developed and studied including evidenced-based, self-directed, and problem-based learning (40, 46-48). In general, learning theories describe how students receive, process, and retain knowledge through the learning process (31, 35, 49). Further, intwined in these topics is the connection with inter/multidisciplinary research (6 items) (16, 38, 46, 48, 50, 51). Forensic and STEM disciplines are characterized by the numerous scientific disciplines, some of which are multidisciplinary, as well as the variability in pedagogies used to transfer knowledge from faculty to student. To strengthen "education outcomes" and the applied practice of STEM disciplines, including forensic science, laboratory courses should be the focus of additional research (50).

Resources (Education and Research)

As with the other most studied themes, educational and research resources (11 items) was repeatedly identified in the grounded theory mixed methods research. For example, in simulation based medical education, resources (educational and research) are needed for translational science (35). McGaghie et al. found that "national research priorities are served from translational educational research [and that] national funding priorities should endorse the contribution and value of translational education research" (35). In research evaluating self-directed learning in internal medicine residency, resources were identified as a needed component for progression through an academic program (31). Resources were also cited as necessary for other higher education initiatives including incorporating innovative approaches such as the "Maker Movement", "Active Learning", and "Social-Emotional Learning" approaches (45, 52-53). Forensic science education and training involve faculty with specialized knowledge and skills, expensive analytical equipment, laboratory space, and additional resources to provide the required information and expertise to enable students to enter a career as a forensic scientist. FEPAC acknowledge in their standards that forensic academic programs must demonstrate that they have "Institutional Support" which must be sufficient to allow the program to achieve its mission, goals, and objectives (54). These resources should provide classrooms, laboratories/facilities, equipment and supplies appropriate for the size and scope of the program.

Quality, Standards, Best Practices, and Policy

Standardization, as well as academic accreditation, which can demonstrate that an institution meets a set of minimum standards, helps to ensure that the education students receive provide a base level of experience and instruction to prepare them for entry into a career in a STEM field such as forensic science. As previously mentioned, FEPAC was created to provide minimum standards for forensic science education. It is essential that future forensic scientists obtain a level of academic/technical competence, communication/ /interpersonal skills, protective mechanisms, adaptive skills, professional attitudes, and ethical judgment (27-28, 34, 36, 39, 45, 53, 55-56). These are all themes identified in this review. With the use of grounded theory and mixed method analysis, the identified themes in this review may provide useful information that applies to forensic science and help to identify key areas that should be focused on for future research.

Other Theories

Socio-cognitive, critical, and spatial skills theories were also explored. In the work by Atit et al., "Spatial skills enable us to manipulate, organize, reason about, and make sense of spatial relationships in real and imagined spaces [and]STEM professionals often employ spatial skills when completing tasks within their domain" (57). As with STEM professionals, forensic scientists need spatial skills to perform their analyses. Atit et al., further found that "…discipline-based education researchers specializing in STEM domains have focused much of their research on understanding how to bolster students' skills in completing domain-specific spatial tasks" (57). Research on problem-based learning, through the understanding of socio-cognitive nature of learning, can help us understand how "conceptions, judgment, and motivation" affects cognitive processes and how environments influence learners and the acquisition of knowledge (49, 58). Critical theory and modeling were also explored in the articles reviewed (32, 41, 46, 59). Modeling allows us to create visual representations of data (through experimentation) to better understand it. Critical theory is an approach that utilizes reflective assessment of society and culture criticism to reveal and challenge power structures (59). Forensic scientists often work in publicly funded law enforcement organizations, such as local and state police departments, which may be operated in a para-military formation with a distinct chain of command or power structure. Forensic scientists are tasked with examining evidence and making conclusions that could potentially influence the outcome of a case. The information that is gathered through the investigative process on victims and suspects may influence the forensic scientists, due to preconceptions they may hold on criminal acts and those that may be involved in them (60).

Conclusion

This review highlights numerous educational research themes that may help us understand and improve educational outcomes in STEM higher education, including forensic science. It was found that a theme may be identified as a topic of study but may also influence other themes and/or thematic groups. Although grounded theory mixed method approaches have not been used in forensic science education research, the identified themes and conclusions in this review may be of benefit to forensic science training. Brown noted that grounded theory methodologies allow for "innovative synthesis" to "organize, analyze and combine concepts from an intermixed selection of quantitative and qualitative research [and] inferring an emerging theory or thesis of new knowledge" (61). It is essential that future forensic scientists obtain a level of academic/technical competence, communication/interpersonal skills, protective mechanisms, adaptive skills, professional attitudes, and ethical judgment. These themes should be evaluated with a focus on forensic science to enhance the education students receive and the skills they start out with in their careers.

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