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CONCEPTS AND MISCONCEPTIONS IN ENGINEERING, TECHNOLOGY AND SCIENCE.
OVERVIEW OF RESEARCH LITERATURE

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ABSTRACT

Effective instructions in Engineering and Technology [E&T] require knowledge of how students understand, and do not understand key concepts in these disciplines. Many studies reported that even high-performance engineering students (with high grades) after four years of college instruction continue to hold significant misconceptions about scientific concepts and have misinterpretations of phenomena (like electricity, force, light). Practical knowledge of engineering students also is limited, and students' ability to solve problems is incomplete. Even with increasing competency, moving from freshman to senior level, students learn how to follow a familiar algorithms (e.g., to solve equations), but often they are unable to explain why they followed those algorithms.

The purpose of this review was to develop a synthesis of research about concepts and misconceptions in engineering and technology, and to reflect these to the work on misconceptions in science. Because the topic of *students' misconceptions* crosses multiple disciplines, the search methodology was guided by a concept map targeting databases such as: ERIC, PsycInfo, Engineering Village-2, Web of Science and ProQuest (Dissertations & Master Theses). Particular attention was paid to education and cognitive psychology research (1995 - 2010) addressing the phenomenon of misconceptions, and recent publications of National Academy Press. The main purpose was to better understand the learning process, and ultimately, to provide a basis for improving student learning of E&T.

Keywords**:** *Concepts, Misconceptions, Science, Engineering, Technology*.

1. INTRODUCTION

The topic of *students' misconceptions* crosses multiple disciplines in science, cognitive psychology, pedagogy, technology and engineering education. Thus, a methodological approach was undertaken to conduct this literature review. No single source assesses academic work in research about misconceptions. The majority of scholarly sources were accessible through the Libraries of Purdue University. The first step in conducting this review was a series of consultations with Purdue University librarians specializing in the areas of science, engineering, education, and psychology. The next step consisted of gathering information from appropriate databases and e-journals, which included: digital library Xplore IEEE, Web-of-Science, ERIC, Engineering Village-2, the Journal of Engineering Education and proceedings of Frontiers in Education (FIE) conferences. A few publications of National Academy Press (NAP) also were overviewed. In addition, the Dissertation and Theses (ProQuest) database was consulted. Searching in databases, keywords were used for every section of this literature review that included but not limited to: *concepts in science*, OR *technology* OR *engineering; students' misconceptions; misconceptions in physics; misconceptions* AND *technology* AND *engineering; conceptual change; cognitive conflict; novices* AND *experts.* These searches constructed many hundreds of matches. The only articles/theses considered were those with keywords in titles or abstracts because they endow an essential means of sorting based on content. The criterion for rejecting or accepting search results was based on the relevance of the title and the abstract's content. Considered papers were only from scholarly established peer reviewed sources.

2. CONCEPTS AND CATEGORIZATIONS

According to Soman (2000), a major motivating force for human beings is the need to make sense of their world. Individuals form their mental models and build cognitive structure from personal experience. "We tend to seek patterns and use those patterns with which we make successful and meaningful explanations…Once new ideas are subsumed into individual's cognitive structure, it becomes part of that person's repertoire of tools used to make sense of the world" (p.4). Rosch (1978) argued that conceptual knowledge is structured hierarchically according to categories. Lakoff (1990) states that understanding of categorization is crucial to understanding cognition. Rosch (1978) also proposed that learners categorize new concepts according to their similarity with existing concepts.

Streveler et al. (2008) referring to Perkins (2006) characterizes concepts as organizers. "Most fundamentally, concepts function as organizers. They carve up the world we already see and posit the unseen. They sort things into plants and animals, living and dead, democratic and autocratic governments, the deductive and the inductive, velocity and mass and momentum" (p. 279). Streveler and colleagues (2008) argued that concepts play a crucial role in how we make sense of the world. "Not only do they allow us to categorize our physical surroundings, but they also impact what we do with what we have categorized" (p. 279). Thompson and Logue (2006) referring to Eggen and Kauchak (2004) defined concepts as ideas, objects, or events that help us understand the world around us.

2.1.Concepts in Science

Literature gives hundreds of definitions and meanings for the word *science*. In general, science is a human search about the truth; it is an investigation of the nature and the world around us. Krebs (1999), referring to the *Webster's II New Riverside University Dictionary* (1994), presented a few definitions of the term s*cience*: Science is:

- Observation, identification, description, experimental investigation, and theoretical explanation of natural phenomena
    - Such activity is restricted to a class of natural phenomena
    - Such activity is applied to any class of phenomena

- Methodological activity, discipline, or study
- Activity that appears to require study and method
- Knowledge that is especially gained through experience (p. 6).

The terms *science*, *engineering,* and *technology* are repeatedly mixed together as a single phrase. In the K-12 level, "science" is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space, and environmental sciences. According to the *Framework for K-12 Science Education,* two major goals for K-12 science education are: "(1) educating all students in science and engineering and (2) providing the foundational knowledge for those who will become the scientists, engineers, technologists, and technicians of the future" (p.1-2). The Committee on conceptual *Framework for K-12 Science Education (2011)* recommends that science education in grades K-12 should be built around three major dimensions. These dimensions are:

1. ***Scientific and Engineering Practices***

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

2. ***Crosscutting Concepts*** that unify the study of science and engineering through their common application across fields:

- Patterns
- Cause and effect: mechanism and explanation
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter: flows, cycles, and conservation
- Structure and function
- Stability and change.

According to *A Framework for K-12 Science Education,* the crosscutting concepts have application across all domains of science. They provide one way of linking across the domains in Dimension 3. These crosscutting concepts are not unique. They echo many of the unifying concepts and processes in the *National Science Education Standards* (1996), the common themes in the *Benchmarks for Science Literacy* (1993), and the unifying concepts in the *Science College Board Standards for College Success* (2009).

3. ***Disciplinary Core Ideas***

Physical Sciences

- Matter and its interactions
- Motion and stability: forces and interactions
- Energy
- Waves and their applications in technologies for information transfer

Life Sciences
  - From molecules to organisms: structures and processes
  - Ecosystems: Interactions, energy, and dynamics
  - Heredity: Inheritance and variation of traits
  - Biological evolution: unity and diversity

Earth and Space Sciences
  - Earth's place in the universe
  - Earth's systems
  - Earth and human activity

Engineering, Technology, and the Applications of Science
  - Engineering design
  - Links among engineering, technology, science, and society.

The *Framework for K-12 Science Education* (2011) also states that for supporting students' meaningful learning, all three dimensions need to be integrated into standards, curriculum, instruction, and assessment.

2.2. Concepts in Technology

To explain the term *technology,* Pitt (1999) defined *technology* as *humanity at work.* From this viewpoint, technology exists as long as humankind exists. Olsen (2007) states that currently technology includes many more factors that were not considered technology in the past (including social structures and bureaucracy systems as controls on what scientists can and cannot do). Many authors argue that the concept of technology may be used in very different senses. Mitcham (1994) distinguished four scopes of technology: namely technology as (1) object, (2) knowledge, (3) activity, and (4) volition. Kroes & Van de Poel (2009) described two meanings of technology:

1. *Technology as a process (activity):* is a collection of processes of designing, developing, producing, maintaining, and disposing of technical artifacts;
2. *Technology as a product (object)*: is a collection of technical artifacts, that is, what comes out of technology as a process in so far as the latter is restricted to the design, making, and maintenance of technical artifacts (p.62).

Rossouw, Hacker and De Vries (2010) argued that in the present time, the nature of Technology Education has changed: it has slowly evolved from focusing on skills to focusing on technological literacy. Thus, conceptual basis for the curriculum is the main issues in the development of Technology Education. Comparing concepts in science and technology, McCormick (2004) argued:

> The concepts that are important to technologists are not usually the concepts related to theories, such as kinetic theory of gases, but those related to laws (such as Boyle's law). Driver et al. (1996) make an important distinction between theories and laws. Laws define empirical relationships (stress, strain, and so on) common in many technological concepts. But these are particular technological concepts, because they relate to particular technologies or areas of technology (p.25).

With support from the NSF and NASA, the International Technology and Engineering Educators Association (ITEEA) developed Standards for Technological Literacy, released in 2000 and revised in 2002 and 2007. The STL is a key document for technology teachers and educators. Twenty standards identified the crucial concepts in technology and the directions for curriculum development in Technology Education. This document presents in-depth content for what every child in Grades K-12 should know and be able to do in order to be technology literate.

STL defined technology as: "innovation, change, or modification of the natural environment in order to satisfy perceived human wants and needs" (p. 22). Thus, a technologically literate person is able to:

1. *Use technology*: successful operation of key products & systems of the time; knowing components of existing macro-systems, or human adaptive systems, and how the system behave;
2. *Manage technology*: ensuring that all technological activities are efficient and appropriate;
3. *Evaluate technology*: being able to make judgments and decisions about technology on an informed basis rather than on an emotional one;
4. *Understand technology*: more than knowing facts and information, but also the ability to synthesize the information into new insights.

In the third edition published in 2007, twenty standards were organized under the five key concepts/themes:

- Nature of Technology
- Technology and Society
- Design
- Abilities for Technological World
- The Designed World.

In 2010, Rossouw, Hacker, and De Vries conducted the Delphi- study with an international group of experts. The purpose of the study was to identify the key concepts to be taught in Engineering and Technology education, as well as relevant and meaningful contexts through which these concepts can be taught in secondary schools. Rossouw, Hacker, and De Vries (2010) argued that ITEEA's Standards for Technological Literacy "typically define what students should know and be able to do in specific content or programmatic areas. In some cases, competencies defined by standards are quite broad; in other cases, the competencies are atomistic" (p. 3). Therefore, the researchers attempted to "identify a set of overarching and unifying concepts that cut across domains, and thus give insight into the holistic nature of engineering and technology" (p. 2). Such identification should help to improve STL-driven curricula by helping learners understand relationships among technological domains.

The results of the study showed that a number of concepts stand out as possible foundations for an engineering and technology education curriculum: "concepts *design* (as a verb), *system*, *modeling*, *social interaction*, and *optimization* were given the highest average score by the Delphi experts. "Second-best" concepts were *innovation*, *specifications*, *design* (as a noun), *sustainability*, *energy*, *materials*, *resources*, *trade-offs*, *technology assessment*, and *invention*" (p. 8). The core concepts, identified by the international expert group, were similar to the concepts from ITEEA's Standards for Technological Literacy conducted as a basis for the US technology education. Also, the experts developed a list of ''umbrella contexts'' addressing personal, societal, and global concerns to Technology and Engineering Education. This list included: *food, shelter* (construction), *water, energy, mobility, production*, *health, security,* and *communication*.

Contexts generally raised more disagreements than concepts. *Medical technologies* were accepted but not entirely by agreement. There were disagreements about *nanotechnology* because it is too difficult to put in practice. There was a trend among experts to retain traditional contexts, like *construction, production, transportation,* and *communication*. The new trend was to seek major social issues and umbrella contexts. As a next step, experts recommended structuring a technological curriculum in two possible ways, according to *concepts* or according to *contexts***.**

> The first option will result in modules like 'Systems', 'Resources' or 'Values' and can be used to teach and learn the concepts in the way that is suggested by the current ideas on concept-contexts learning (learning a concept in a series of different contexts, which gradually leads to an insight on a more abstract level, and thereby also transferability to new contexts). This can be called a 'systematic' or 'disciplinary' approach…The second option results in modules like 'Water', 'Energy', or 'Mobility' and can be used to show the versatile nature of the concepts. This can be called a 'thematic' approach and currently seems to be the most popular internationally. Both options are justifiable and a curriculum could even contain a combination of modules based on both options (p.14).

Results of the present study can be very helpful for curricula developers in Technology and other disciplines. Rossouw, Hacker, and DeVries (2010) recommended considering the use of their lists of concepts and contexts to rethink Engineering and Technology education frameworks and teaching methods. The authors hoped that their lists "….may help, for instance, to bring more conceptual coherence in the now very extensive list of Standards for Technological Literacy that was developed and is now implemented in the USA" (p. 15).

2.3. Concepts in Engineering

Contemporary research literature offers many broad definitions and various perspectives of engineering. For example, Koen (2003) states that engineering is "the strategy for causing the best change in a poorly understood situation within the available recourses" (p. 7). Ketahi et al. (2009) argued that engineering is "the process of designing the human- made world" (p. 27). Published by the National Academy Press, *Framework for Science Education* (2010) provides two similar meanings:

1. Engineering is a "discipline that uses scientific principles to design and build useful tools and technologies, and to respond to real-world challenges and design opportunities" (p. 1.11).
2. It is "a disciplined process of using resources and human creativity to achieve human purposes by creating and applying technologies" (p. 5.23).

Another definition is given by the Accreditation Board for Engineering & Technology ABET (2007): "Engineering is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs" (p.2). Sheppard et al (2008) reinforce the definitions given by the U.S. Department of Labor: "Engineering is the application of the theory and principles of science and mathematics to research and develop economical solutions to technical problems…it is the link between perceived social needs and commercial applications" (p.3). The National Academy of Engineering (in *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*, 2005) defined the term *engineer* as a professional who, by applying scientific knowledge and technical skills, knows how to satisfy the society needs in products and artifacts. Lewis (2005) wrote that "the main task of engineers is to apply their scientific and engineering knowledge to the solution of technical problems, and then optimize those solutions within the requirements and constraints set by the material, technological, economic, legal, environmental, and human-related considerations" (p. 41).

Despite the variety of definitions, the concept of engineering is not easy to identify clearly. Jamison (2009) explained that "one of the main difficulties in discussing the context of engineering is that engineering, like science, art, and other forms of human creativity, has a range of different meanings and functions: commercial, economic, social, professional, cultural, and human " (pp.49-50). Figueiredo (2008) discussed four major dimensions of engineering:

1. *Engineer as Scientist*. This dimension is "inspired by the basic sciences views of engineering as the application of the natural and exact sciences, stressing the values of logics and rigor, and seeing knowledge as produced through analysis and experimentation. In this dimension research is preferred… and seen as the activity leading to higher recognition" (p. 94).
2. *Engineer as Sociologist*. Engineers are seen as "social experts, in their ability to recognize the eminently social nature of the world they act upon and the social complexity of the teams they belong to. The creation of social and economic value and the belief in the satisfaction of end users emerge as central values" (p. 94).
3. *Engineer as Designer*. In this dimension, engineering is "the art of design… it includes exploring alternatives and compromising. In this dimension, which resorts frequently to non-scientific forms of thinking, the key decisions are often based on incomplete knowledge and intuition, as well as on personal and collective experiences" (p.94).
4. *Engineer as Maker/Doer*. Engineering is "the art of getting things done"(p. 94).

In every dimension, an engineer requires to have a specific type of knowledge. Sheppard (2008) stated that "the knowledge that engineers must bring to bear in their work includes knowing how to perform tasks, knowing facts, and knowing when and how to bring appropriate skills and facts to bear on a particular problem" (p. 5). According to Sheppard et al. (2008), engineering knowledge can be divided into three major categories:

1. Knowing that (declarative knowledge) - it is important for the dimension when the engineer is recognized as scientist;
2. Knowing how (procedural knowledge)- the engineer performs as technologist;
3. Knowing why (strategic knowledge) - needed when the engineer is problem-solver and decision-maker, including social, economic, and ethical aspects.

Sheppard (2008) also noted that ethical responsibilities recently became a feature of engineering. Focus on ethical consequences of engineering practice was not critical for past. Now ethics issues can significantly influence engineering decision- making. "Because engineers' work directly affects the world, engineers must be able and willing to think about their ethical responsibility for the consequences of their interventions in an increasingly interlinked world environment" (p. 8).

In *Engineering in K-12 Education*, released by the National Academy of Engineering in 2009, Katehi et al. claimed that "there is no widely accepted vision of what K–12 engineering education should include or accomplish. This lack of consensus reflects the ad hoc development of educational materials in engineering and that no major effort has been made to define the content of K–12 engineering in a rigorous way" (p. 7). Despite the absence of common concepts and standards in engineering education, Ketahi et al. (2009) propose three General Principles for K-12 Education, which may enhance ITEEAS' Standards for Technological literacy and help educators develop valuable curricula on local and State levels:

- *Principle 1:* K–12 engineering education should emphasize engineering design;
- *Principle 2:* K–12 engineering education should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills;
- *Principle 3:* K–12 engineering education should promote engineering habits of mind (pp. 4-5).

On the post-secondary level, engineering programs are guided by ABET (2007) recommendations, which described what every student should know and be able to do at the college level.

3. ALTERNATIVE CONCEPTS AND MISCONCEPTIONS

Numerous studies in recent years have shown proof that many students do not understand concepts in science in the same way as experts and scientists. Concepts in science overlap in many ways with the concepts in engineering and technology. Thus, students' incorrect understanding of scientific concepts and natural phenomena affects engineering and technological performances. Smith, DiSessa, and Roschelle (1993) observed that novice interpretations of scientific concepts and expert perceptions of scientific knowledge are very different. Tomita (2008) argued:

> When students enter science classrooms, they often hold deeply rooted prior knowledge or conceptions about the natural world. These conceptions will influence how they come to understand their formal science experiences in school. Some of this prior knowledge provides a good foundation for further formal schooling, while other conceptions may be incompatible with currently accepted scientific knowledge. The importance of prior knowledge and the struggle to replace that knowledge with or help that knowledge evolve into scientifically-sound knowledge has spurred a large tradition of research in developmental and instructional psychology and science education (p. 9).

Despite the fact that the term of *student misconceptions* is widely used in scientific literature, not all researchers agree to define students' prior knowledge as misconceptions. The term *misconception* has many synonyms. Tomita (2008) summarized synonyms existing in the literature for this term. Primarily referred to as *misconceptions* (Wandersee, Mintzes, & Novak, 1994), these conceptions also are called *naive conceptions* (Champagne & Klopfer, 1984), *nonscientific beliefs, pre-instructional beliefs* (Chinn & Brewer, 1993), *intuitive knowledge* (Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001), *phenomenological primitives or p-prims* (DiSessa, 1983), *facets* (Minstrell, 1992), or *alternative frameworks* (Carey, Evans, Honda, Jay, & Unger, 1989). "Regardless of terminology, the point is to recognize that a students' prior knowledge is embedded in a system of logic and justification, although one that may be incompatible with accepted scientific understanding" (Tomita, 2008, p. 10). Smith, diSessa, and Roschelle (1993) argued that clarification of the terms *misconceptions*, *alternative beliefs*, and *preconceptions* is necessary:

> The prefix to the most common term - *misconception* - emphasizes the mistaken quality of students' ideas. Terms that include the qualifier – *alternative* - indicate a more relativist epistemological perspective. Students' prior ideas are not always criticized as mistaken notions that need repair or replacement but are understood as understandings that are simply different from the views of experts…Students' *alternative conceptions* are incommensurable with expert concepts in a manner parallel to scientific theories from different historical periods…*Preconceptions* and *naïve beliefs* emphasize the existence of student ideas prior to instruction without any clear indication of their validity or usefulness in learning expert concepts. However, researchers who have used them have tended to emphasize their negative aspects. This epistemological dimension emphasizes differences in content. The content of student conceptions (whether mistaken, preexisting, or alternative) is judged in contrast to the content of expert concepts (p. 159).

3.1.Misconceptions in Science

Brown and Hammer (2008) described a typical example of students' misconceptions about scientific concepts (in physics). A student may be able to apply **F = ma** accurately to find **a** if given **F** and **m**, but if asked to explain what the equation means might say something like: "*It means that the force of an object depends on how heavy it is and how fast it's moving*. This involves alternative ways of thinking about all three variables – force as a property of an object, mass as weight, and acceleration as speed" (p. 128). Brown and Hammer (2008) argued that even after physics instruction, college graduates continue to have serious misconceptions about various concepts like force, energy, and temperature. Even the best and brightest students are not learning what educators may think they are learning from their science education Referring to Halloun, (1998) and Hammer (1994) Brown and Hammer stated:

> By the time they are in college, many students do not expect physics to make sense, and the problem gets worse as a result of college physics courses … The research of the 1980s thus showed that students could come away from instruction having memorized some facts and solution algorithms but with their conceptual understanding essentially unchanged (p. 128).

There is a wide range of literature about misconceptions in science, which often discusses the understandings of physical phenomena by students. Incorrect ("unscientific") perceptions are called misconceptions. There are a few stages that the majority of literature follows:

1. Describe a phenomenon (like force, temperature, light)
2. Ask students what they think about this phenomenon. "In physics education research, it is common to gain insight into conceptual knowledge by showing the student a physical situation and asking what will happen and why" (Streveler, Litzinger, Miller, & Steif , 2008, p. 281).
3. Analyze the answers (correct and incorrect perceptions of this phenomenon)
4. Make an attempt to understand how the incorrect meaning of the phenomenon occurs
5. Discuss robustness of student misconceptions

6. Often literature about misconceptions in science is connected to the cognitive psychology literature and mentions conceptual change theories. Every theory of conceptual change has its own explanation for students' misconceptions and offers its own mechanism for overcoming these misconceptions. In other words, depending on theoretical framework, the answer to the question about *why students have misconceptions* may be different.

Streveler et al. (2008) argued that "one of the main issues in psychology literature about conceptual knowledge is whether the students' knowledge is organized in a coherent structure or whether it is fragmented" (p.280). Therefore, the literature often considers student misconceptions from two perspectives, alternative ideas that are *organized as theory* or ideas that are *elements or fragments*. Brown and Hammer (2008) argued that these two perspectives on misconceptions shifted educators' understanding of student errors:

> Whereas previously students were seen as just making mistakes, now they were seen as scientists applying alternative theories to interpretations of phenomena. This helped to make sense of why students seemed "resistant" to new ideas and it drew attention to the need to understand their existing theories (p. 130).

3.2.Misconceptions in Technology

The literature about *misconceptions in science* has more solid theoretical background than literature about *misconceptions in technology*. Goris and Dyrenfurth (2010) stated that such situations have occurred because research about misconceptions in science is more expanded and more deeply developed than research about misconceptions in technology. Despite that Technology became an integral feature of modern culture, public opinions about technological impact on life are often uncertain and vague. Referring to recent Gallup polls, Havice (n.d.) pointed out some frequent public confusion about technology:

1. Majority of people do not know what technology is;
2. The general public had a very narrow definitions of technology as compared to a broader view of technology held by experts of technology, engineers, and scientists;
3. There are common confusions between *Technology Education* and *Educational Technology*. Havice explained that Technology Education is the school subject that teaches ABOUT technology. It deals with technological knowledge and concepts. The goal of *Technology Education* is technological literacy. *Educational Technology*, on the other hand, is a teaching method that teaches WITH technology. It deals with instructional hardware and software. The goal of *Educational Technology* is to improve teaching and learning.
4. There is also frequent mixing of terms *science* and *technology*, identifying technology as a science. Responding to that, Havice (n.d.) described the key differences between those domains:

Technology:	**Science:**
- Is study of the human made world	- Is study of natural world
- Is created by people	- Is discovered by people
- Is invention and innovation	- Is observation and description
- Ask "How?"	- Ask "Why"?

Because of wide definitions of the term *Technology,* web-search shows a broad spectrum of literature with absolutely different aspects and themes. Some common examples, in addition to those listed previously, are shown below:

- Misconceptions about use of technology (in this case the meaning of technology is 'tools') are influenced by gender, or different perceptions of technology by female and male students.
- Technology in relation to innovations. Therefore, misconceptions about technology are presented as misconceptions about innovations.
- Perceptions of technology, and misunderstandings about technology of business management; managers are resistance to new technologies.
- Misconceptions of elderly people about new technologies (e.g. iphones, computers).
- There are conceptual misunderstandings in biotechnologies or others technologies (e.g. nano-, computer-, medical).
- Misconceptions about the use of technology in K-12.
- Misunderstandings about distance learning, online-education, and multimedia.
- Often literature about *misconceptions in engineering* includes the term *technology.*

3.3.Misconceptions in Engineering

The research literature about *misconceptions in engineering* also has extensive content and approaches, but this domain is less investigated than *misconceptions in science*. However, a general content of the literature devoted to *misconceptions in engineering* is more clearly defined compared to the literature about *misconceptions in technology*. One of the common public mistakes is recognition of engineers as scientists and confusing *engineering* with *science*. *The Framework of Science Education* (2010) states that despite the diffuse line between science and engineering, the outcomes of engineering differ vs. the outcomes of science. Engineering outcomes "…are products and processes, rather than theories; it serve specific purposes and solve specific problems… scientific inquiry typically begins with a particular, detailed phenomenon and moves toward generalization, while engineering design applies general rules and approaches to focus on a particular solution" (p. 2-6).

Lewis (2005) also explains different roles of engineers and scientists: "unlike scientists who proceed within the framework of scientific laws, engineers employ heuristic laws to arrive at design solutions. Heuristics do not guarantee solutions, but they reduce the search time in solving a problem" (p. 41). The other difference between engineering and science is that engineering problems are usually ill-defined (Jonassen, Strobel, and Lee, 2006; Jonassen, 2003). A few "right" decisions for one task can co-exist together depending on the resources required for performing the task.

Engineering activity requires the solution to concrete problems. Thus, literature about *misconceptions in engineering* often defines various complications related to 'the problem solving process'. The web-search results with the key-phrase *misconceptions in engineering* include the following themes:

- Discussions (with descriptions of numerous research studies) of the very disseminated phenomenon that many engineering students (including seniors who had completed science courses) still do not understand key relationships between scientific concepts.

- Explanations of misconceptions in engineering by already existed theories of conceptual change. Authors often refer to the cognitive psychology literature. “Issues include the basic organization of students' conceptual knowledge and explanations about why some misconceptions tend to be more difficult to correct than others” (Streveler et al., 2008, p. 280).
- Complaints on rigor curriculum and math requirements for engineering- major students.
- Misconceptions related to *Engineering Education*. This literature discuses what curriculum changes are necessary to make the engineering profession more popular are presented.
- Various gender misconceptions about engineering and discussions of women roles in engineering.
- Discussion of robustness of misconceptions and resistance to overcome the misconceptions.
- Many authors agreed that research about misconceptions in engineering is undeveloped; there are more questions than answers. This field needs more investigation.

Various approaches to students’ misconceptions in Science, Technology, and Engineering are summarized in Table1.

Table 1. Different Approaches in the Literature about Misconceptions in Science, Technology, and Engineering.

Literature	**Approaches and Discussed Themes**
Misconceptions in Science	- Describe a phenomenon (like force, temperature, light). - Ask students what they think about this phenomenon, what will happen and why. - Analyze the answers (correct and incorrect perceptions of the phenomenon). - Make an attempt to understand how the incorrect meaning of the phenomenon occurs. Refer to cognitive psychology and conceptual change theories. - Discuss robustness of student misconceptions. - Discuss how to improve the curriculum and teaching methods.
Misconceptions in Technology	- People do not know what technology is and how to define it. - Thinking about technology only in term of computers. - Confusing about *Technology Education* vs. *Educational Technology*. - Confusing the terms *science* and *technology*. - Recognizing technology as applied science. - Misconceptions about technology and gender; male vs. female roles in technological environments. - Misunderstandings of business managers about technology and their resistance to new technologies; - Conceptual misunderstandings in bio, nano-, computer-, or medical technologies. - Misunderstandings about the use of technology in K-12. - Misconceptions about distance learning, online-education, and media. - Often literature about *misconceptions in engineering* includes the term

	technology.
Misconceptions in Engineering	- Confusing the terms *engineering* and *science.* - Discussions of high academic performance of senior engineering students with poor conceptual understanding of science concepts. - Explanations of science misconceptions by theories of conceptual change. Referring to the cognitive psychology literature. Why are some concepts more difficult than others? - Complaints on rigor curriculum and math requirements for students majoring in engineering. - Misconceptions related to *Engineering Education.* Discussions about curriculum improvement to make the engineering profession more popular. - Various gender misunderstandings about engineering and women's roles in engineering. - Discussion of robustness of misconceptions and resistance to overcome misconceptions. - Agreement that research on misconceptions in engineering is undeveloped; there are more questions than answers. This field needs more investigation.

CONCLUSION

This brief summary of concepts & misconceptions (and their comparisons) should be helpful for researchers and educators in STEm disciplines. The majority of literature about misconceptions describes students' struggles about scientific concepts. There are not too many sources that illustrate misconceptions specifically in technology or engineering without overlapping with science. To know how *misconceptions* in those three domains differ (or similar to) each other, we need clearly understand *what are concepts* (and categorizations) in engineering, science and technology. We attempted to develop an overview of research about concepts and misconceptions in engineering and technology, and to reflect this to the work on misconceptions in science.

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