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# Fostering Emotional Engineers: Revisiting Constructive Thinking in Engineering Education

Andrea Arce-Trigatti
*Tennessee Technological University*, atrigatti@tntech.edu

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## Cover Page Footnote

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# Fostering Emotional Engineers: Revisiting Constructive Thinking in Engineering Education

*Andrea Arce-Trigatti, Tennessee Tech University*

For the last two decades, national organizations in the field of engineering have called on postsecondary institutions to adopt more comprehensive pedagogical reforms aligned with cultivating constructive thinking practices—those that foster new knowledge creation through social interaction (Arce et al., 2015; Gilbuena, Sherrett, Gummer, Campagne, & Koretsky, 2015; Grasso & Burkins, 2010; Sanders & Geist, 2016). The purpose of this training is to move away from producing technical content experts to more holistic-style professionals, fluent in both technical and professional (e.g., communication, entrepreneurial) skills (Grasso & Burkins, 2010). This shift to utilize pedagogical practices that fosters more holistic-style engineers aligns with a larger consensus for teaching strategies that promote constructive thinking practices that could potentially benefit female students (Gilbuena et al., 2015; Litchfield, Javernick-Will, & Maul, 2016). However, despite theories that would posit the increased participation of female engineering students in these new learning environments, overall there is evidence that the opposite is occurring (Hatmaker, 2013; Jones, Paretti, Hein, & Knott, 2010; Jones, Ruff, & Paretti, 2013; Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012; Wolfe & Powell, 2006, 2009a; Verdin, Godwin, Kirn, Benson, & Potvin, 2017). To explain this discrepancy between the theoretical benefits of constructive learning environments and the actuality of female students' experiences, the argument can be made that there is an inherent misalignment between the paradigm shifts occurring in the postsecondary instruction of engineering fields and the traditional values that have historically characterized these disciplines.

The role of emotions—an aspect often policed within the field of engineering—elucidates where this misalignment is occurring. Emotions play a large role in the multidisciplinary elements, communicative strategies, and design aspects of the 21st century conceptualization of engineering (Jonassen, 2011; Pribram & Harding, 2002). However, fostering emotional engineers (i.e., those proficient in emotional literacy) is an idea rarely emphasized by those advocating for a paradigm shift in the way traditional engineering disciplines are taught at the postsecondary level (Ahmed, 2014; Felder & Brent, 2015; National Academy of Engineering [NAE], 2005, 2010; Pribram & Harding, 2002). Better understanding the role of emotions in engineering could hold the potential for addressing this aforementioned misalignment by evaluating how the implicit bias towards socially-constructed gendered identities prevalent in engineering fields manifests in constructive learning environments (Ahlqvist, London, & Rosenthal, 2013; Moss-Racusin et al., 2012; Verdin et al., 2017). Further, by exploring the role of emotions in constructive thinking and how they can be fostered by specific teaching practices, implications for improving pedagogy for all engineering students could be determined.

The purpose of this contribution is thus to examine this misalignment by taking a philosophical lens to understand the role of emotions in engineering and constructive thinking in order to better the pedagogical strategies utilized as part of this paradigm shift. I begin by outlining the implicit gender bias in engineering, how it relates to emotions, and how this bias misaligns with the constructive thinking practices promoted in the paradigms shifts happening in the field. I continue by explicating the

contribution of emotions to constructive thinking through a feminist, philosophical lens, which features Thayer-Bacon's (2000) holistic understanding of constructive thinking. This follows with findings of recent gender-based communication studies in engineering education and the potential negative ramifications the devaluation of emotions has for female students (Jones et al., 2013; Wolfe & Powell, 2006). Jaggar's (1992, 1998) philosophical contributions then help us understand these studies by detailing emotions' historical association with female thought, its overall impact on the construction of knowledge, and how emotions can be valued as part of the engineering discipline. Pedagogical implications for postsecondary educators in the field of engineering provide the concluding remarks for this work.

## Implicit Bias in Engineering: The Mind and Body Bifurcation

Traditionally, the field of engineering has focused on the attainment of technical knowledge that could contribute to the creation of products and the effective implementation of processes (Litchfield et al., 2016). Such focus values conventional forms of critical thinking, or what scholars typically identify as the logical aspects of problem solving, over other cognitive functions or skills, such as sociocultural or socioemotional skills (Jaggar, 1992; Heilman, 2012; Tarule, 1996; Thayer-Bacon, 2000). Within Euro-Western contexts, the valuation of these skills has tended to favor males over females, as the bifurcation of mind (e.g., thinking) and body (e.g., emotions) has historically assigned the former to males and the latter to females (Pribram & Harding, 2002; Thayer-Bacon, 2000). To this point, Ahmed (2014) contends that " 'emotion' has been viewed as 'beneath' the faculties of thought and reason" and associated with women who were "less able to transcend the body through thought, will, and judgement" (p. 4). As a result, traditionally "soft" skills—denoted as such due to the gendered characteristics associated with body language literacy—are, in turn, affiliated with Euro-Western female social identity markers (Ahmed, 2014; Gilbuena et al., 2015).

This type of implicit bias is entrenched in engineering and in other, traditional science disciplines (Grunspan, Eddy, Brownell, Wiggins, Crowe, & Goodreau, 2016; Verdin et al., 2017). Implicit bias that is gender based in engineering can be described as a tendency to favor males over females due to an engrained belief that such socially constructed identity markers are associated with traits more favorable to, or aligned with, the profession (Grunspan et al., 2016; Moss-Racusin, Molenda, Cramer, 2015). Further, the myth that the scientific method helps to filter emotion from inquiry helps drive the illusion of the dispassionate scholar, when, in reality, all inquiry is motivated by some type of motivation guided by emotion (Jaggar, 1992; Rossi & Aarnio, 2012). Rossi and Aarnio (2012) label such environments as "malestream" (p. 172), wherein the culture necessitates a separation between reason and emotion to be successful. This implicit bias—the split between mind and body, thought and emotions—continues to propagate the image of females as "invaders" (Verdin et al., 2017, p. 2) in this field.

Part of the initiatives of the comprehensive engineering education efforts at the postsecondary level speak to this issue, seeking to create a more holistic-style professional which purports the development of these "soft," or professional skills (Felder, 2006; Felder & Brent, 2015; Grasso & Burkins, 2010; Oskam, 2009; Thayer-Bacon, 2000). The 2005 publication

of the National Academy of Engineering's (NAE) Vision for the Engineer of 2020 provides evidence to this point. In this document, the NAE (2005) states that the key to succeeding in a more globally interconnected field is training engineers to pioneer new ideas by connecting professional skills to technical content in order to advance innovative ideas. This training requires a multifaceted expansion of the skills already prerequisite for engineers so that students may be more socially aware of their contributions, be considerate of their resources, and display more ingenuity in their practice (Gilbuena et al., 2015; NAE, 2005, 2010; Oskam, 2009).

From a pedagogical perspective, this shift necessitates a move from critical (i.e., traditionally male-centered, logical, and rational problem thinking skills) to constructive thinking (dual-gender centered, logical, emotional, multidisciplinary, problem thinking skills) (Jaggar, 1992; Tarule, 1996; Thayer-Bacon, 2000). Constructive thinking is rooted in the belief that knowledge is constructed through continual interaction with peers and the environment, thus emphasizing the professional skills associated with the holistic-style professionals (Driscoll, 2005; Felder & Brent, 2015; Oskam, 2009; Shayer, 2003). Adopting a more constructive thinking pedagogical framework subsequently correlates with these postsecondary reforms as it offers a foundation that permits interdisciplinary interaction, increased engagement with peers, and a focus on expanding the diversity of thought through an appreciation of multiple perspectives (Anderson, 2013; Arce et al., 2015; Felder, 2006, 2012; Felder & Brent, 2015; Sanders & Geist, 2016). Further, this pedagogical shift emphasizes the use of skills more aligned with those traditionally assigned to female gender roles (e.g., emotional, social) (Jaggar, 1992; Grunspan et al., 2016; Thayer-Bacon, 2000). Litchfield and colleagues (2016) emphasize this point by positing that such a shift inherently incorporates various elements of the motivational frameworks typically embraced by female students, providing a tangible way to apply and transfer relative fluency of relational skills to learning.

However, despite the increased recruitment and participation of female engineering students, studies have demonstrated that the increased use of collaborative aspects associated with constructivist teaching practices may also be negatively impacting the learning processes of this same student population (Moss et al., 2012; Rosser, 2009; Tonso, 1996; Wolfe & Powell, 2009a, 2009b). For example, a study by Wolfe and Powell (2009b) argued that because female engineering students tend to incorporate emotion-laden characteristics into their speech patterns, they are often overlooked by their male peers within group contexts. Policing practices within engineering student groups (e.g., dismissing student comments, not allowing students to speak, not incorporating student ideas) adversely impact female student learning, therefore undermining the value of this style of teaching and the contributions of female students in their training and that of their male peers (Moss-Racusin et al., 2012; Moss-Racusin et al., 2015; Wolfe & Powell, 2006, 2009b). The result is a pedagogical quandary: the very environment that may attract female students to engineering is also the very environment where they are most exposed to policing practices by their male peers. This misalignment speaks to a deeper issue rooted in the implicit bias that characterizes engineering and how this bias interacts with the epistemological nature of constructive thinking and the pivotal role played by emotions within this construct.

## The Epistemology of Constructing Knowledge

As part of the exploration into the philosophical intricacies of this misalignment, the theoretical foundations of the pedagogical shift occurring in the engineering discipline must be detailed. To begin, the epistemology of constructivism merits defining. Constructivism is a pedagogical construct rooted in the philosophical tradition that contends that learning is a process of continual learner self-construction through the learner's interaction and conceptualization of reality (Anderson, 2013; Driscoll, 2005). Specifically, all learners conceive an understanding of relevant knowledge and skills, whether physical, abstract, or social, by imposing their own concepts on reality to make sense of what they are experiencing (Driscoll, 2005; Larson & Lockee, 2014; Piaget, 2000). Constructivists value multiple perspectives, believing that there is no absolute truth within the learning process; knowledge then is malleable and situated within the learners' personal, social, and contextual understanding (Fuson, 2009; Shayer, 2003). In accordance, this theory advances that within effective learning environments, students play an active role and teachers must engage the learner with the content through this interaction (Munari, 1994; Shayer, 2003). Constructivism then differs from other pedagogical approaches in that learning is not inherently a solitary activity; in actuality, social constructivists argue that learning is a process that necessitates, and is influenced by, an individual's interaction with the environment (Shapiro & Permuth, 2013; Shayer, 2003). Thus, in order to expand the understanding of a particular concept, conversations with others through collaborative projects or other types of interactions must occur (Larson & Lockee, 2014).

## Who Can Construct Knowledge? The Gender Perspective

As noted, the mechanics of knowledge construction has often favored certain forms of contributions (e.g., logical, critical, and reasoning) which are associated with a socially-constructed male proclivity to these forms of thinking (Heilman, 2012; Jaggar, 1998; Jorgenson, 2002). This implicit bias dismisses several voices from the conversation of knowledge construction and the processes associated with constructive thinking. To counter this perspective, prominent female scholars have actively reevaluated the notion of what cognitive tools contribute to knowledge construction in order to integrate voices previously excluded (Belenky, Clinchy, Goldberger, & Tarule, 1986; Goldberger, Tarule, Clinchy, & Belenky, 1996; Jaggar, 1992, 1998; Thayer-Bacon, 1995, 2000). However, delving into the different philosophical perspective presented by these scholars is beyond the scope of this work. Rather, I wish to focus on Thayer-Bacon's (2000) contribution to constructive thinking as she intricately weaves the work of other prominent scholars to unpack the gendered issues often characterizing the construction of knowledge. In doing so, she effectively outlines the role that other tools (e.g., emotions) play in knowledge construction, which provides the philosophical foundations upon which the rest of this work builds. Thus, albeit the abundant scholarship in this area, Thayer-Bacon's (2000) contribution, complemented with scholars that emphasize the major points of her work, are specifically featured because her conceptualization of constructive thinking provides an important avenue with which to delineate how the mechanics of thinking are

interpreted from a socially-constructed identity (i.e., gender) and how it can be leveraged to establish more holistic cognitive practices.

Through her book, *Transforming Critical Thinking: Thinking Constructively*, Thayer-Bacon (2000) underscores that her conceptualization of constructive thinking is founded on Belenky and colleagues' (1986) concept of constructive knowing. To this point, she suggests that this term emphasizes

> the idea that thinking is something we actively construct within ourselves, as psychologists such as Vygotsky (1934/1962) and Piaget (1980) have argued, as well as its emphasis on the idea that thinking is socially constructed, as Berger and Luckman (1966) and other sociologists (Mead, 1934) have argued. (Thayer-Bacon, 2000, p. 5)

Constructive thinking in this sense is the ability to shape and change one's understanding of the world through his or her interaction and exposure to various ideas, people, and environments (Belenky et al., 1986; Tarule, 1996; Thayer-Bacon, 2000). This dialogue is what makes meaning, and therefore knowledge construction, through the course of social exchanges in the form of conversations, possible (Tarule, 1996). Within this type of transaction, women's sense of self and knowing is continuously influenced by their positioning within these exchanges and what is valued or not valued as part of these exchanges (Jorgenson, 2002; Tarule, 1996).

For Thayer-Bacon (2000) constructive thinking, then, is a holistic process that is anchored in two main pillars. The first pillar is the integration of four critical thinking tools (i.e., reasoning, intuition, imagination, and emotion); the second is the successful utilization of relational learning (Thayer-Bacon, 2000). To help readers understand how both pillars are intertwined, Thayer-Bacon (2000) employs the metaphor of a quilting bee. Regarding the first pillar (i.e., four critical thinking tools) she illustrates that each critical thinking tool can be represented by an action or physical instrument observed as part of the image of the quilting bee (Thayer-Bacon, 2000). Although readers can create their own associations, Thayer-Bacon's (2000) version of this metaphor is constructed as follows: reasoning can be associated to the rulers, scissors, and straight pins as it helps us "define and clarify" our ideas; intuition is the needle and thread that helps us to make connections and tie together our ideas; imagination is the materialization of the patterns and design of the quilt, as it allows us to envision alternative ideas and perspectives; and, finally, emotions are the drivers of our interests, represented by the colors and textures of the fabric we chose in the quilt (p. 148). Further, she explains:

> Quilters use their emotional feelings and their imagination, as well as their intuition and reasoning, to help them decide which materials to use and what designs to create in the quilt. Their personal voice—their soul, will, who they are as subjective human beings—is what decides. With the help of all of these tools they are able to construct quilts of knowledge. (Thayer-Bacon, 2000, p. 11)

Thus, like a rope, these tools are stronger when they are intertwined, weaker when they are used as singular threads (Thayer-Bacon, 2000).

The quilting bee metaphor also offers a helpful visualization of her understanding of the second pillar of constructive thinking: relational learning. In her work, Thayer-Bacon (2000) describes relational learning

as an epistemology that embraces two assumptions. The first assumption is an extension of Benhabib's notion that all beings are socially "embedded and embodied" within their lived contexts (as cited in Thayer-Bacon, 2000, p. 2). The second relates to the nature of knowledge wherein Thayer-Bacon (2000) argues that it is "something that people contribute to; they do not find knowledge 'out there' or 'in here" (p. 2). Further, each individual must contribute through various, and distinct, multifaceted mechanisms and interactions (Jorgenson, 2002; Tarule, 1996; Thayer-Bacon, 2000). For Thayer-Bacon (2000), the quilting bee then offers a space in which idea exchanges are the key purpose. Similar to other collaborative processes, this space must truly be democratic for distinct tools to be fully utilized and incorporated into the quilt, or learning process (Belenky et al., 1986; Tarule, 1996; Thayer-Bacon, 2000). Although not all ideas must be incorporated into the quilt, the actual space offered must allow for a pluralistic appreciation of everyone's contribution and an authentic exchange between individual interactions to the final product: the construction of knowledge (Tarule, 1996; Thayer-Bacon, 2000).

## The Misalignment

### The Emotional Rift

Ultimately, Thayer-Bacon's (2000) conceptualization of the quilting bee as a metaphor for constructive thinking is useful for understanding the limitations of the engineering paradigm shift hitherto described. In developing her argument, she critiques traditional philosophers for historically focusing on reasoning as the only tool valued in helping learners develop knowledge, a perspective consequently furthered by other feminist scholars in the field (Belenky et al., 1986; Goldberger et al., 1996; Jaggar, 1992, 1998; Tarule, 1996; Thayer-Bacon, 2000). To this point, Thayer-Bacon (2000) argues:

> The writing of a socially relational epistemology is motivated by the desire to expand what epistemology means, to include the qualities of knowing that have historically been viewed as detrimental or distracting to the obtaining of knowledge, qualities such as emotional feelings, imaginations, and intuitions that are usually linked to women rather than men. (Thayer-Bacon, 1995, p. 3)

The crux of this critique stems from the idea that learning in the form of reasoning is often depicted as a solitary act via cognitive connections formed within individual thought, which overlooks the apparent social element of knowledge construction (Belenky et al., 1997; Goldberger et al., 1996; Tarule, 1996; Thayer-Bacon, 2000).

As noted, this social element is particularly relevant to the current paradigm shift in engineering wherein the focus is on developing constructive thinkers that leverage social interaction for knowledge construction (Arce et al., 2015; Felder & Brent, 2015; Jorgensen, Arce-Trigatti, Sanders, & Arce, 2019; Litchfield et al., 2016; Sanders & Geist, 2016). Such shifts are nevertheless occurring in a field which is still male dominated and associated with the norms and roles of traditional Euro-Western, masculine social identities (Heilman, 2012; Moss-Rascusin et al., 2012; Verdin et al., 2017). Heilman (2012) underscores this misalignment by explaining that gender stereotyping can account for disparities in professions like engineering which are often thought of as rational, logical, and less emotional. Thus, despite advancements within engineering that arguably recognize that other cognitive tools (e.g., imagination,

intuition, and relational learning) are, in addition to reasoning, valuable contributors to constructive thinking, this implicit bias with regards to the contribution of emotions lingers (Moss-Rascusin et al., 2012; Moss-Rascusin et al., 2015).

This misalignment can be evidenced by the role that emotions play in the forming of holistic-style professionals. Only recently are emotions being acknowledged in the development of these 21st century engineers, regardless of the fact that such elements are a vital part of the communication, design, and social relevancy skills deemed desirable in this new conceptualization (Goldberg & Somerville, 2015; Grasso & Burkins, 2010; Jonasson, 2011; NAE, 2005, 2010). For example, Goldberg and Somerville (2015) relay that a few of the most successful pedagogical breakthroughs in engineering were profoundly emotional in nature, a realization that became, "excruciatingly hard for a couple of engineers to understand and embrace" (p. 4). Even when acknowledged, the scope of the emotions acceptable in engineering professionalism are limited (e.g., courage, joy, excitement) (Goldberg & Somerville, 2015). In consequence, it can be argued that emotions are not yet actively being noted as a vital part of the type of constructive thinking associated with the paradigm shifts related to the engineering fields. The devaluing of emotions as a tool for constructive thinking, and its historical link to female qualities, could consequently explain the challenges that female students face in collaborative environments, despite the hypothetical advantages awarded to them through the use of constructive thinking strategies (Tarule, 1996; Thayer-Bacon, 2000).

## The Evidence

**Gendered communication patterns.** As communication plays an essential role in constructive thinking practices, I explore the role of emotions in gendered communication patterns to gain insight on the misalignment described above. By doing so, the manifestation of implicit bias in the form of biased communicative practices can be evaluated and linked to this inherent misalignment. From the extant literature focusing on female and male subjects of varying ages living within a Western context, an important distinction of the communication styles between females and males has been identified in that such styles are the reflection of emotions within overall communication (Grysman, Merrill, & Fivush, 2017; Hatmaker, 2013; Palomares, 2008). Within the Western contexts studied in this research, females tended to denote more emotion-laden speech patterns than males in a majority of evidenced-based communication studies (Iosub, Laniando, Castillo, Morell, & Kaltenbrunner, 2014; Palomares, 2008; Tenenbaum, Ford, & Alkhedairy, 2011). For example, in a study comparing female and male communication styles among children aged 6-8 years old, Tenenbaum and colleagues (2011) found that females tend to use more emotion labels (i.e., words that indicate an emotion, like pleasure, affection, surprise, fear, distress, concern, indifference, anger, or dislike) than their male counterparts when describing a story or a similar experience. In addition, females use more collaborative speech patterns (i.e., building on their partners' statements in positive ways) than males (Tenenbaum et al., 2011).

Mehl and Pennebaker (2003) concluded from their study that women express more positive emotions than men when they are in a naturalistic setting (i.e., lived, daily, social-environment encounters) interacting

with others. Naturalistic settings offered participants a space to interact with their peers in environments as they would within a normal, everyday encounter (Mehl & Pennebaker, 2003). In contrast, when on their own or in other solitary contexts outside of a naturalistic setting (for instance, writing an essay) the emotional proclivities of female communication patterns decline (Mehl & Pennebaker, 2003). Further, women have been found to be better senders of emotion- laden speech patterns, particularly of signals of pleasantness, disgust, distress, and anger, than their male counterparts when speaking in similar settings (Wagner, Ross, & Winterbotham, 1993). Palomares (2008) conducted a controlled experiment wherein both males and females were asked to communicate via electronic messages to a respondent whose gender identity was solely manipulated by the level of stereotypically feminine characteristics of supportiveness within the communicative patterns utilized. The results showed that females utilized emotion significantly more than males when the gender salience (i.e., awareness of gender as a social category) between the responder was high (Palomares, 2008).

Despite this evidence, scholars caution that perhaps it is not emotionality that is impacting female speech patterns, but rather specific sociocultural contexts that dictate how women should speak versus how men should speak (Fischer, 1993; Heilman, 2012; Tenenbaum et al., 2011). This is important to note as the valuing of certain speech patterns in particular contexts might also be a sociocultural phenomenon (Wolfe & Powell, 2006). Scholarship on this type of sociocultural influence in gender-based communicative patterns links to social theories, like Eagly's (1987) Social Role Theory, which posits that norms, traits, and behaviors assumed to be associated with specific genders are often reinforced through cultural messages. Rogus-Pulia, Humbert, Kolehmainen, and Carnes (2018) sum this idea up nicely in the following:

> In order to conform to such expectations, men have been socialized to adopt traits and behaviors that are "agentic," such as being logical, independent, assertive, strong, bold, and decisive (Eagly & Wood, 1991), whereas women have been socialized to adopt traits and behaviors that are "communal," such as being nurturing, relational, emotional, supportive, modest, and warm (Eagly & Wood, 1991, p. 1600)

Within male dominated professions, such as engineering, these assumptions are arguably pervasive and have reinforced the type of gender roles often associated with success and achievement in these types of careers (Concannon & Barrow, 2010; Hatmaker, 2013; Jones et al., 2013; Jorgenson, 2002; Tonso, 2006).

**Emotions and collaboration.** More collaborative environments, as often incorporated in the pedagogy related to constructive thinking practices, arguably help female students succeed in traditionally male dominated disciplines (Litchfield et al., 2016; Wolfe & Powell, 2009a). The argument behind this hypothesis is that collaborations are meant to allow females a space to leverage fluency in relational skills and engage with the content in a manner more effective than in a more traditional setting that favors the individualistic tendencies of male students (Jones et al., 2013; Litchfield et al., 2016; Wolfe & Powell, 2009a; Thayer-Bacon, 2000). As Borrego, Karlin, McNair, & Beddoes (2013) denote, it is an environment wherein different types of leadership skills, including design, community building, and supportive

communication, are valued for the overall success of the group. In theory, as outlined above, collaborative work is a setting in which students must work with one another to not only build on their own content knowledge, but to construct and create new knowledge from their interaction with one another (Driscoll, 2005; Tarule, 1996; Thayer-Bacon, 2000). As illustrated with the quilting bee metaphor, it is a space that allows for everyone to contribute to the construction of knowledge (Thayer-Bacon, 2000). This setting thus allows female students an opportunity to actively contribute to the discipline and be valued for their perspectives, in turn positively influencing their self-efficacy and sense of belonging (Jones et al., 2010; Jones et al., 2013; Wolfe & Powell, 2009a).

Communication based research within the engineering context, however, provides evidence to suggest that this advantage for female students is not necessarily pervasive. Some studies have even linked higher attrition rates among female engineering students to the increased use of group work and collaboration with their male counterparts (Ahlqvist et al., 2013; Jones et al., 2013; Tonso, 1996, 2006; Wolfe & Alexander, 2005; Wolfe & Powell, 2006, 2009a). As Jones and colleagues (2013) explain, within group settings, negative female stereotypes are further reinforced because of the frequency of the students' interactions, ultimately leading to female students feeling inadequate and not aligned with the discipline. Further, the results from their study, which surveyed college-aged students regarding various stereotype indicators (e.g., engineering identification, gender identification, gender stereotype endorsement, and engineering ability perceptions) indicate that males were more likely to hold negative stereotypes of females' engineering abilities (Jones et al., 2013). Wolfe and Powell (2009a) focus on communication patterns and highlight that male students respond negatively to female communication patterns which are, as aforementioned, laden with emotional speech styles that include indirect criticism and self-belittlement statements (e.g., "Okay this is just me being a grammatical person" or "But, that's just me being picky") (p. 10). In accordance, male students, who are more task-oriented and self-promotional in their communication styles, perceive their female peers as weak, less assertive, and, ultimately, unfit colleagues (Wolfe & Powell, 2006, 2009a, 2009b).

Thus, instead of having the intended effect of accelerating understanding and communication between female and male students, collaborative work in the form of constructive thinking practices might be undermining female interest and self-efficacy within engineering (Ahlqvist et al., 2013; Jones et al., 2013). As suggested by scholarship in this area, this tendency undervalues emotion-laden speech patterns as an indicator of less refined skills traditionally valued in this field (Jones et al., 2013; Moss-Rascucin et al., 2012; Rogus-Pulia et al., 2018; Verdin et al., 2017). With the shifting of the engineering paradigm toward the development of constructive thinkers who can more readily navigate fluctuating communicative structures and fluid social-contexts, the assumptions that gender-based communicative patterns hold for successfully collaborating in these new spaces is paramount (Ahlqvist et al., 2013; Borrego et al., 2013; Grasso & Burkins, 2010; Tonso, 2006). To better understand the devaluation of the role of emotions in engineering as part of the implicit bias in the field, it is pertinent to overview, historically and philosophically, the entrenched biases held against this constructive thinking tool and the female identity markers to which it is assigned.

## The Scientific Value of Emotions: A Philosophical Argument

Although the gendered association of emotions with females has hitherto been established, it is essential to further unpack the historical and philosophical foundations that led to this characterization in order to affect a change in narrative regarding this concept for engineers. For this purpose, I turn to Allison Jaggar and the thoughts featured in her work, *Love and Knowledge* (1992), where she provides a historical and epistemological exploration regarding the place of emotions in the construction of knowledge. In addition, her work, *Sexual Equality as Parity of Effective Voice* (1998), furthers the message of this piece and elucidates the social and scientific value of emotions, and therefore the feminine voice. Her arguments add to the clarification of the bifurcation of the engineering profession illustrated above, wherein emotions are often dismissed by a socially constructed appreciation for reason (Jaggar, 1992, 1998). These ideas are further supported by feminist scholars who have re-conceptualized her work in various social and academic applications.

To understand the divergence of emotion from knowledge construction, Jaggar (1992) first attempts to provide a definition for emotions:

> Emotions . . . are wrongly seen as necessarily passive or involuntary responses to the world. Rather, they are ways in which we engage actively and even construct the world. They have both mental and physical aspects, each of which conditions the other. In some respects, they are chosen, but in others, they are involuntary; they presuppose language and a social order. (pp. 152-153)

As not all emotions are universal, it can be presupposed that certain emotions, if not all, are a consequence of experience and cultural exposure (Ahmed, 2014; Jaggar, 1992). To further this point, Jaggar (1992) explains that, "Women appear more emotional than men because they, along with some groups of people of color, are permitted and even required to express emotion more openly" (p. 157). In some instances, such connections are permitted as part of the primitive programming associated with various cultural groups (Ahmed, 2014). For example, Ahmed (2014) explains that as part of the formation of cultural value and traditions, there exists a false hierarchy between emotions and thought/reason, as often times both are intertwined into a larger, cultural narrative representative of distinct social groups.

Furthering this point, Jaggar (1992) cites the anthropologist Catherine Lutz who describes the dualism between cognition and affect (the former associated with males, the latter with females), which has influenced positivist thought, as a consequence of longstanding, Euro-American, cultural constructions. Pribram and Harding (2002) note that the exclusion of emotions as part of the cognitive skills associated with critical thinking has been culturally engrained by the association of emotion as an uncontrolled sensation rather than a valuable tool for evaluation. In engineering culture, this has propagated the illusion of the dispassionate scholar and the emergence of outlaw emotions in traditionally male dominated contexts by underpinning how emotions are understood as primitive, cognitive patterns rather than as tools for enhanced synthesis (Ahmed, 2014; Jaggar, 1992, 1998). Simply put, Rossi and Aarnio (2012) state, "Emotions are implicitly linked with non-academic life, femininity and weakness" (p. 172).

To rebuke this cognition/affect dualism would allow for emotions to be acknowledged as socially constructed elements, ultimately permitting their use as organizational tools founded in individual social judgments and personal values (Ahmed, 2014; Jaggar, 1992; Rossi & Aarnio, 2012). To clarify, Jaggar (1992) refines the socially constructed understanding of emotions by highlighting their culturally laden implications and linking this association to increased judgment and evaluation: a vital acumen for the construction of knowledge. She contends,

> The most obvious significance of this sort of example is illustrating how the individual experience of emotion focuses our attention selectively, directing, shaping, and even partially defining our observations, just as our observations direct, shape, and partially define our emotions. (Jaggar, 1992, pp. 153–154)

In this regard, emotions are working in confluence with cognition in that they shape experiences in as much as experiences define the construction of emotions (Rossi & Aarnio, 2012). In consequence, Jaggar (1992) argues that emotions therefore help direct inquiry, guide research, and explore new areas of investigation.

Yet, as evidenced by the findings of the aforementioned studies, the values that emotions bring to help motivate the construction of knowledge have long been severed by the positivist ideal that inquiry must be objective (Rossi & Aarnio, 2012; Verdin et al., 2017). Jaggar (1992) explains, "Positivism views values and emotions as alien invaders that must be repelled by a stricter application of the scientific method" (p. 156). In turn, because the scientific method has been traditionally associated with the social domain of males, the relegation of emotions to the feminine stereotype has rendered this cognitive tool not fit for scientific exploration, illuminating the findings of Wolfe and Powell (2006) regarding the interaction between male and female engineering students. Such disjuncture creates the development of outlaw emotions - those that are "conventionally unacceptable" or go counter to the status quo - like anger towards not being respected in a certain discipline (Jaggar, 1992, p. 160).

According to Jaggar (1992), individuals who develop outlaw emotions usually silence them and assimilate into the dominant status quo in order to survive. For example, she points to the fact that, "Even where women have a formal right to speak, informal norms often impose pressures to speak in a style and language that are culturally masculine" (Jaggar, 1998, p. 188). Often women comply to avoid the risk of being ignored. She concludes that this type of participation is, in actuality, "repressive tolerance" in which formal freedom of expression is tethered to social constructs that dictate what is appropriate in what situation (Jaggar, 1998, p.188). Thus, in the case of engineering, the feminine voice is never actually appreciated as a respected asset to expand learning, as it is linked to emotion - a tool deemed unfit for knowledge construction.

Much like Thayer-Bacon (2000), Jaggar (1992) views emotions as an essential tool for advancing inquiry and ultimately calls for a reconsideration of knowledge construction in which emotions hold a proper place in the process. In particular, she posits that:

> rather than repressing emotion in epistemology it is necessary to rethink the relation between knowledge and emotion and construct conceptual

> models that demonstrate the mutually constitutive rather than oppositional relation between reason and emotion. (Jaggar, 1992, pp. 156-157)

Further, until women achieve some form of parity of effective voice, they will continue to be discredited, dismissed, and silenced in social contexts in which their gendered and emotion-laden speech is devalued (Jaggar, 1998; Tarule, 1996). "Language is not a neutral medium," she explains (Jaggar, 1998, p. 188). As such, a female perspective, when valued, permits a contribution to knowledge construction that is unique to the female experience (Jaggar, 1992, 1998; Tarule, 1996). The alternative, epistemological model proposed would thus appreciate the continuous interaction between the human experience and how individuals are conceptualized in those experiences (Jaggar, 1998; Rossi & Aarnio, 2012; Tarule, 1996). In sum, such a model, "would show how our emotional responses to the world change as we conceptualize it differently and how our changing emotional responses then stimulate us to new insights" (Jaggar, 1992, p. 164).

## Concluding Remarks

The description provided by the NAE's (2005) Vision for the 2020 Engineer is one that requires engineers to be socially responsible, innovative, and aligned with the notions of constructive thinking, a primarily social endeavor for learning. Although pronounced strides have been made in the instruction of engineering at the postsecondary level (Arce et al., 2015; Felder & Brent, 2015; Grasso & Burkins, 2010; Jorgensen et al., 2019; Sanders & Geist, 2016), implicit gender biases associated with the field are misaligned with the purpose of the pedagogical shift currently underway (Moss-Racusin et al., 2012; Moss-Racusin et al., 2015; Verdin et al., 2017). In particular, the overt, conventional masculinization of the field has negative repercussions with regards to the integration of emotions which are primarily associated with those that do not fit the profile of a traditional, content-expert engineer (Litchfield et al., 2016; Sochacka, Guyotte, & Walter, 2016). Fostering emotional engineers, consequently, is a characteristic essential to the development of a holistic-style engineer, yet rarely an initiative that is integrated into the reformation of pedagogical practices for engineers (Goldberg & Somerville, 2016; Sochacka et al., 2016). Moreover, the need for the integration of emotions in all aspects of engineering design, reflective thinking, and dynamic communication are undervalued and ultimately lost as part of this misalignment (Borrego et al., 2013; Gilbuena et al., 2015; Goldberg & Sommerville, 2015; NAE, 2005, 2010; Tonso, 1996, 2006). When it is integrated, only particular emotions are hailed as valuable contributors to learning (e.g., trust, courage, joy, excitement, openness), wherein outlaw emotions are seldom noted as worthy in the scientific inquiry process (Goldberg & Sommerville, 2015; Jaggar, 1992, 1998).

As discussed, it is precisely this misalignment which denotes emotions as not a valuable tool for constructive thinking (Ahmed, 2014; Jaggar, 1998; Rossi & Aarnio, 2012). Further, such misalignment not only risks rendering the pedagogical shift within the engineering discipline incomplete, but also potentially detrimental to female students (Jones et al., 2013; Verdin et al., 2017; Wolfe & Powell, 2006, 2009a). One particular example of the manifestation of this issue rests with the gendered communication patterns embodied by different student populations. The scholars highlighted in this contribution

point to such communication differences, wherein female students employ more emotion-laden speech styles than males, as a factor that contributes to their dismissal within the increased collaborative landscape of the engineering discipline (Ahlqvist et al., 2013; Grysman et al., 2017; Palomares, 2008; Tonso, 2006; Wolfe & Powell, 2006, 2009a).

In an attempt to explore this pedagogical dilemma, I analyzed the epistemological notions associated with constructive thinking using Thayer-Bacon's (2000) contributions to underscore the role of emotions in this form of collaborative learning. Her ideas contend that constructive thinking is much more inclusive than simply coupling imagination and peer interaction to the traditionally valued skill of reasoning (Thayer-Bacon, 2000). Jaggar's (1992, 1998) work then elucidates that, "without emotion, human life would be unthinkable," and furthers that the notion of the dispassionate scholar stems from a fictitious, positivist ideal that research can and should be objective (i.e., emotionless) (p. 155). In accordance, valuing emotion in scientific inquiry is necessary as all scholars, not just females through their communication patterns, display emotional proclivities in their work (Rossi & Aarnio, 2012). Indeed, all research questions, design decisions, and socially-motivated engineering solutions are guided by personal interests which are motivated by emotions and essential to the development of holistic-style engineers (Goldberg & Sommerville, 2015; Grasso & Burkins, 2010; Jaggar, 1992; Thayer-Bacon, 2000).

## Pedagogical Implications

Pedagogically, there are several implications that derive from analyzing the role of emotions in constructive thinking teaching practices. The first implication calls for engineering educators to accentuate the role of emotions as a vital part of different aspects of the profession: primarily in design, reflection, and communication (Litchfield et al., 2016; Sochacka et al., 2016). Engineering is inherently a human-centered profession that requires design and process expertise that pays attention to socially generated challenges and the navigation of human actions and interactions (Jonassen, 2011; Sochacka et al., 2016). The generation of engineering solutions (i.e., designs), then, is also human-centered. According to Jonassen (2011), a designer is the central component of the design process and, in consequence, the designer's person (e.g., feelings, emotions, and proclivities) is intimately integrated into the design. As design is a reflective process necessitating that engineers acknowledge their own interpretations and understandings of what is being developed or communicated, such engineering aspects are therefore dependent on acknowledging emotions as important to propelling these processes forward (Jonassen, 2011; Sochacka et al., 2016). Further, communication between individuals within - and external to - the engineering fields, is dependent upon the level and understanding of sociocultural and socioemotional aspects that help to navigate the intricacies of dynamic, communication patterns (Gilbuena et al., 2015; Sochacka et al., 2016).

In addition, there is a need for engineering educators to make the connection to their students between emotions and the new professional skills that comprise the character of the holistic-style engineer. The depiction of the holistic-style engineer demands proficiency in in "soft" or professional skills (e.g., communication, teamwork, self-awareness, and cultural sensitivity) (Gilbuena et al., 2015; Grasso & Burkins, 2010; Sochacka et al., 2016). Such proficiency is dependent upon a level of

emotional understanding and adaptability that allows for self-awareness and reflection to decipher distinct interpretations and synthesize ideas for effective communicative navigation. For example, teaching engineering students that the emotional aspect of design is not simply aesthetic (e.g., making prototypes pretty) but, in actuality, an essential part of the development of the design (e.g., deciding on the type of material used based on a passion for environmental sustainability issues) (Sanders & Geist, 2016; Sochacka et al., 2016). Thus, incorporating the acknowledgement and appreciation of emotions as part of pedagogical objectives within engineering holds the potential to bolster the acquisition of professional skills and better integrate student populations that are already more socially aligned with these characteristics (Borrego et al., 2013; Gilbuena et al., 2015; Goldberg & Sommerville, 2015).

Finally, there is need for engineering educators to emphasize how emotions effectively mitigate the success of collaborative work geared towards knowledge construction. To differing degrees, educational scholars suggest that collaboration is impacted by the interactions developed by all group members. As the climate of a group is socially constructed and impacted by the discourse exercised between the interactions of the constituents, communication becomes the crux of a group's organizational culture (Thompson Klein, 2005). In turn, communication patterns that assist in establishing common language among members from differing backgrounds are essential for navigating complex, organizational cultures (Levine, Allard, & Tenopir, 2011). Communication is thus essential to foster collaborative group dynamics in that individual differences are not mitigated or overlooked, but successfully negotiated to allow for a space of mutual exchange between the group constituents (O'Donnell & Derry, 2005; Thompson Klein, 2005). Thus, teaching students to appreciate various gendered communicative patterns in a way that integrates - rather than dismisses - the ideas fostered by their peers will help to address the silencing of student populations that actively utilize these forms of communication.

As evidenced by the studies featured in this work, it is not enough to create a pedagogical shift within engineering if traditional characteristics associated with the implicit gender bias in this profession mitigate the effective implementation of vital elements pertaining to this shift. Moreover, not addressing this misalignment does a disservice to the discipline as several of the desired professional skills identified as part of the successful holistic-style engineer are founded on a proficient level of understanding the implications of emotions as a constructive thinking tool (Thayer-Bacon, 2000). Fostering emotional engineers is thus a call for engineering educators to teach their students that emotions are a central aspect of the creation of holistic-style engineers (Grasso & Burkins, 2010; Litchfield et al., 2016). By training future, holistic-style engineers that emotions are an integral part of the design, reflection, and communicative aspects of this human-centered profession, students may be able to better navigate the intricacies that accompany human-centric challenges and dynamic interactions (Jonassen, 2011; Sochaka et al., 2016). Such efforts also hold the potential to affect positive change in addressing the implicit bias entrenched in this field.

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