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Story-Driven Learning in Biomedical Engineering: Quantifying Empathy in the Context of Prompts and Perceptions

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Abstract
Storytelling can be valuable for developing empathy and enhancing communication, allowing individuals to make connections with themselves and others. In this work, we sought to understand the potential of story-driven learning, the process of developing stories to connect defining moments of the past and consider future goals, within the context of engineering. We describe a required, non-traditional undergraduate course that employs this pedagogical approach for biomedical engineering students to encourage them to integrate, reframe, and make meaning of their diverse experiences. We then detail our study, where we sought to explore: 1) how unique story prompts may elicit different aspects of empathy, in terms of sharing, thinking about, and caring about others; and 2) how students' self-perceptions of empathy correspond to external evaluations of empathy from stories shared. We quantitatively assessed aspects of empathy in (n = 20) students' stories submitted around four specific prompts using the External Evaluation of Empathy Rubric (EEER). The empathy observed in these stories was then compared to the students' self-reported empathy, as measured using the Interpersonal Reactivity Index (IRI). Our findings illustrate that encouraging students to think about their future and their goals often yields the highest scores for emotional, cognitive, and action-oriented components of empathy. Prompting students to describe confronting or responding to a failure led to more self-focused stories, where students were less likely to describe any kind of societal-level change. The data also provided evidence for relationships between internal and externally evaluated empathy, with a significant and large positive relationship for the cognitive aspect. We hope that this research will encourage other educators to see the value of story-driven learning and to employ this innovative approach to future lessons and activities. In addition, we suggest that the selection of story prompts can be important and may impact the empathy components elicited.

1 Introduction

Developing effective solutions in engineering requires empathic skills not only in the practice of design but also in interpersonal, collaborative approaches to meet the needs of diverse sets of stakeholders [1, 2]. Although the value of empathy is clear, how it can be attained or strengthened is less well-defined. The learning activities that educators in STEM fields may employ vary from approaches utilizing role playing to offering service-learning experiences [3]. One potential way to cultivate empathy is the use of **story-driven learning** (SDL), defined as the intellectual process of creating, telling, and listening to reflective, evidence-based stories [4].

Storytelling is beneficial for inquiry and knowledge construction and is key to promoting communication, psychosocial development, and a humanistic approach to others [5–8]. Beyond

personal narratives and relaying events, storytelling has been shown to enhance presentations and is recommended to contextualize facts and other information in engineering [9]. Additionally, SDL has been used to develop personal and professional competencies and to encourage students to reframe their own experiences both retrospectively and prospectively [10, 11]. It can also allow individuals to articulate their plans and assist in capturing the needs of others.

Within our institution, we infused SDL into a required, non-traditional undergraduate course in the biomedical engineering (BME) department called "The Art of Telling Your Story" [12]. Whereas other works have considered how SDL could help students define their identity and their self-concept [4, 10, 12], our research extends the prior knowledge to explore how SDL, and specific prompts, could present in stories as components of the construct of empathy. Zaki's model (2019) guided our investigation, a framework for empathy that considers its emotional, cognitive, and action-focused aspects. In our study, we sought to answer the following research questions (RQs):

- **RQ1:** *How do unique story prompts elicit different aspects of empathy from Zaki's model, including sharing, thinking about, and caring about others?*
- **RQ2:** *How do biomedical engineering students self-perceptions of empathy correspond to external evaluations of empathy from stories shared?*

We elaborate further on Zaki's model and empathy in Section 2. We then detail "The Art of Telling Your Story" and its prompts in Section 3. In Section 4, we describe our quantitative investigation to answer our research questions. These methods include both 1) our external evaluation of aspects of empathy present in stories crafted around specific prompts'; and 2) a comparison of observed empathy from each prompt to students' self-assessed empathy. We report the results of the study in Section 5. In Section 6, we present the discussion, where we offer our interpretation of the findings as situated within the literature. We then provide the limitations in Section 7 and the conclusions in Section 8.

2 Background and Theory

This section is broken up into defining empathy and our conceptualization of it based on Zaki's model [13], in Section 2.1. Next, we consider methods others have used to cultivate empathy in Section 2.2. We then describe the evaluation of empathy in Section 2.3.

2.1 Defining Empathy

Over time, empathy has been approached and defined in distinct ways. One of the first recorded depictions of the concept was by Aristotle who applied the term "em-pathein" to consider "animation of the inanimate" [14, p. 180]. Later references to the notion arise from German philosophers under the label of "Einfiühlung" [14–16]. Its origin has been associated with Johann Gottfried Herder in 1800 [14–16], in reference to the perception of natural phenomena to "look for similarities to the human and thus ascribe human feelings to them" [16, p. 303]. However, the term itself is linked to Robert Vischer regarding the sentiments that arise in response to viewing works of art in 1873 [15]. The English translation of this word is "feeling into" or what we refer to as "empathy" [15, 16].

Just as the term itself has evolved, so too has its conceptualization. Psychologists and social scientists have studied empathy from a different perspective. In these fields, empathy is viewed as

a multidimensional construct comprised of both cognitive and affective components. Smith in 1759 [17] and Spencer in 1870 [18] were the first to recognize the distinctions between what they called intellectual versus instinctive, or what is now called cognitive versus emotional/affective components of empathy. Cognitive aspects relate to intellectual processes that allow someone to understand another's perspective accurately, while affective aspects stress the emotional facets of sharing another's perspective and being moved to help. Following the work of Smith and Spencer, researchers focused almost exclusively on either the cognitive or affective aspects of empathy treating them as separate until the 1900s [19].

In the 1970s and 1980s, there was a movement toward the integration of these separate empathy research areas and with it a growing view that "the cognitive and affective components of empathy comprise an interdependent system in which each influences the other, and which never can be fully understood as long as research efforts concentrate on one aspect to the relative exclusion of the other" [19, p. 3]. Researchers such as Coke et al. [20] and Iannotti [21] performed many of the initial studies exploring integrated cognitive and affective aspects of empathy and its effect on behavior.

Although it has been argued that empathy is situational, scholars have described empathy as a trait, disposition, skill, ability, process, orientation, and/or professional state [22–24]. Konrath and Grynberg have argued that empathy "encompasses both cognitive elements and emotional ones, and can also be applied to trait and situational empathy" [22]. In this general definition, empathy involves "feeling care and concern for others and imagining their perspectives."

Our research was informed by Zaki's (2019) framework, which considers empathy in terms of affective, mental, and action-oriented components [13]. According to Zaki, **sharing** is the affective component of empathy, which is also described as emotional empathy, experience sharing, and personal distress. **Thinking about** is the mental component that entails cognitive empathy, mentalizing, and theory of mind. Meanwhile, **caring about** is the action-focused component, which includes motivational empathy, compassion, and empathic concern.

As illustrated in Figure 1, we considered how crafting and sharing stories may influence the aspects of sharing, thinking about, and caring about others. In this figure, the white arrows are used to describe the potential influence these components may have on each other. Comparatively, the yellow-dotted arrows suggest the potential links that certain story prompts could reveal. This framework guided the development of our RQs as well as the analysis and interpretation of our findings.

2.2 Cultivating Empathy

There are a number of approaches educators have employed towards the goal of cultivating empathy in students [3]. Engagement with community partners as part of an engineering design course has been described as a way to enhance empathy and students' interpersonal interactions [25]. Moreover, application scenarios via role play have been shown to be valuable for improving empathetic communication [26]. Role play can allow students to take on worldviews that may be distinct from their own through consideration of alternative perspectives while crafting empathetic and non-empathetic responses.

Other scholars have described additional ways to foster perspective-taking. Small group

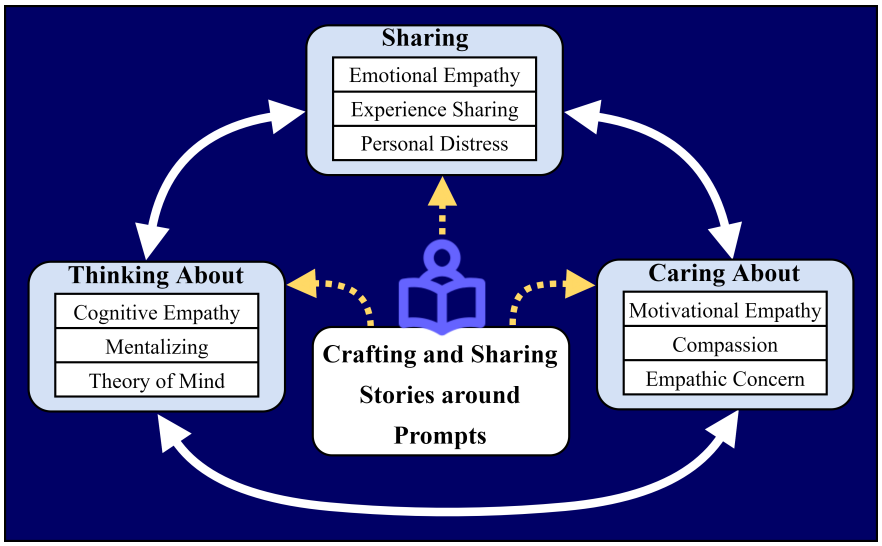

Figure 1: Our examination of how crafting and sharing stories around prompts may influence Zaki's mode of empathy, adapted from [13, p. 178]

discussions on case studies have been utilized towards this goal while also providing a space to initiate conversations around ethical reasoning [27]. In addition, game design has been demonstrated to encourage students to think about considerations such as the target audience, narrative, and tone [28]. Apart from learning to prototype and test designs, game creation has been shown to "help players form an affective bond with another person with a different subjectivity than their own through their avatar and the objects in the game" [28, p. 188].

Immersive virtual reality has also been suggested to be effective for improving perspective-taking [29]. For example, an application was developed that combined video-based technology, storytelling, and "embodied perspective taking" [30]. While such approaches represent an exciting new direction, in our work, we focus exclusively on SDL and explore the impact of providing students with differing prompts.

2.3 Evaluating Empathy

Empathy is often defined using internal self-assessments, as we previously described already in greater detail [31]. The Interpersonal Reactivity Index (IRI) is one such psychometric instrument frequently used in engineering to explore individual differences in empathy [19]. It includes the consideration of four components, measured through sub-scales: Perspective-Taking (PT), Fantasy (FS), Empathic Concern (EC), and Personal Distress (PD).

In the IRI [19, 32], PT considers the tendency to integrate others' psychological viewpoint. FS measures the tendency to use one's imagination to place oneself in fictional situations, such as those in books, movies, and/or plays. EC evaluates individual tendencies to feel sympathy and compassion for "unfortunate others." Finally, PD explores the feelings of distress and discomfort that may arise in reaction to "tense interpersonal settings." Each of these four sub-scales is comprised of seven items answered on a 5-point Likert scale ranging from "Does not describe me well" to "Describes me very well."

When contextualizing Davis' IRI [19] within the framework of Zaki's model of empathy [13], there is some overlap between the IRI sub-scales and empathy components. We describe each further below, as these connections are employed in the analysis of our research:

- **Sharing**: The affective/emotional component of Zaki's model aligns with the affective/emotional subscale of Personal Distress (PD).
- **Thinking About**:The focus on cognitive processes aligns with the cognitive subscale of Perspective Taking (PT).
- **Caring About**: The compassion and "empathic concern" that motivates action to help others maps directly to the Davis IRI subscale with the name, Empathic Concern (EC).

To better understand the links that may exist between students' self-perceptions and empathy observed in artifacts they develop, we compared the correlation between the scores on these subscales of the IRI and the external evaluation of empathy rubric (EEER), a tool for determining components of empathy as described by Zaki's framework [31].

3 The Art of Telling Your Story

"The Art of Telling Your Story" is a course for 3^{rd}/4^{th} year students in BME. The course itself entails weekly assignments posted on Canvas, in-class sharing of stories, and student participation in the community as responses to Canvas posts and stories presented. A summary of the course, taken from the syllabus, is as follows:

> *Why are stories and narratives important for engineers? Because great engineers are great storytellers. They capture and tell the stories of the people they care about, the people they are designing for. Through stories, engineers identify the problems that need solving, helping ensure their work truly makes a difference. And through stories, engineers inspire others to join their efforts, helping them write a new and better story for the future. So, it is a leadership skill. And one more thing: by learning to tell your stories, you learn more about yourself. In this course, you will learn to tell your stories in a variety of ways for different audiences.*

As part of the framing of the course, the instructors seek to "create a safe environment where sharing freely is supported and respected." The learning objectives for the course include those shown below:

1. Identify moments in their journey that tell a specific story.
2. Use the basic structure of stories to create, iterate, and refine stories from their journey.
3. Deliver a story with commitment and energy.
4. Provide constructive feedback in a peer review process.
5. Integrate constructive peer feedback in order to iterate and refine stories.
6. Reflect on integrative connections across their experiences both inside and outside the classroom.

7. Have a collection of stories that shows you have an entrepreneurial mindset – meaning, you are someone who is curious about the rapidly changing world, you make connections among different things you know about, and most important of all, you seek to use your skills to make the world a better place, to create value for yourself, others, and society.

Working towards these objectives, the course instructors developed story prompts to allow the students to reflect on key points in their trajectories while also encouraging them to see their growth. The process involved input from three different individuals, who iteratively refined the content. While we do not explore all of the course prompts in this work, part of the impetus of this research was our desire to explore how variation may elicit different components of empathy (as articulated in RQ1).

4 Methods

To quantify students' empathy and the aspects of empathy that may be present in stories developed around specific prompts, we took a two-fold approach. We first administered Davis' IRI [32] as a self-reported measure of students' perceived empathy. Then, we evaluated perceived aspects of empathy that might appear within stories submitted to The Art of Telling Your Story, employing the external evaluation of empathy rubric that we developed and tested in a prior study [31]. All the students included in the analysis consented to completing the IRI and allowing us to use their artifacts. We also want to note that the procedures and consent language were approved by our Institutional Review Board before any studies were conducted.

4.1 Participants

Data was collected and analyzed from BME students enrolled in The Art of Telling Your Story during the Fall 2021 and Spring 2022 semesters. Although a wider pool of students were enrolled in the course and submitted assignments, we only analyzed the stories of students who consented to allow us to use their submissions for the research. While this included $n = 23$ initially, one student dropped the course and two additional students did not complete the IRI, resulting in a total pool of $n = 20$ students whose stories were included in our evaluation.

4.2 Data Collection: Story Prompts

We selected four prompts to analyze students' responses to specific topics in homework submitted, as shown in Table 1. We chose these particular homework submissions intentionally to ensure the data included complete stories crafted rather than students "reactions" to stories others shared, interviews conducted with another, or prompts related to students' "selling" themselves professionally or pitching an idea they had. The rationale for these decisions was that we wanted to understand the individual's responses and application of story-driven learning rather than their reports or reactions to something another stated.

4.2.1 Self-Reported Empathy

Self-reported empathy was measured using students' scores on the IRI, with a focus on the sub-scales described already. Responses were collected at the start and end of the semester in Qualtrics. Note, there were no significant changes in students' pre- and post-semester scores in empathy (as measured using paired t-tests), and as such, the pre-semester scores were used as a measure of their self-reported empathy levels.

Session	In-Class Topic	Story Assignment	Homework
Week 3	Explore Success Outside the Classroom	Write a new story about a success you had at Georgia Tech beyond your classroom experiences. This might involve extra-curriculars, playing in the marching band, serving as a TA, a Greek Life happening…	D3: Write up and turn in your story
Week 5	Confronting/responding to "failure"	Develop a story about when you experienced failure.	D5: Write up and turn in your story
Week 12	Working backwards – if you know where you are going, how do you get there?	My Future Perfect	D12: Write for 10 minutes every day. Don't stop. Don't lift your pen from your paper or your fingers from the keyboard and each day outline a new possibility for your future. Be sure to include details. Share entries from two days.
Week 15 (Final)	Five-Minute About Me Talks	Develop your talk and work with peers in small groups to improve your five-minute presentation about you, your goals and how/why you can make it happen.	Continue to improve on your About Me presentation. Be sure to include photos and other archival material to enrich the experience. DFinal: Submit story.

Table 1: Prompts analyzed including the session covered, in-class topic, story assignment, and homework assigned, where "D" indicates deliverable

4.2.2 External Evaluation of Empathy

We applied the External Evaluation of Empathy rubric [31] to quantify aspects of empathy described by Zaki's model. This rubric considers each empathy component along several dimensions and uses four quality performance levels:

- **Strongly Evident**: Displays or articulates this and/or considers the implications clearly. Provides multiple applicable examples and/or strong evidence.
- **Evident**: Displays or articulates this and/or considers the implications sufficiently. Provides some applicable examples and/or evidence but may also provide some that are irrelevant.
- **Somewhat Evident**: May display or mention this and/or consider the implications rudimentarily. No examples or evidence provided.
- **Not Evident**: Fails to display or mention this and does not consider the implications. No examples or evidence provided.

These quality performance levels were linearly rated, assigning scores values from 0-3, along each dimension described in Table 2. As shown, sharing is defined by two dimensions, and caring about and thinking about are each defined by three.

Two raters independently rated each story and then met to negotiate on the final rubric rating for the analysis. Internal consistency was assessed using a linear weighted Cohen's kappa ($\hat{\kappa}_w$), a method that considers the degree of disagreement between raters and applies weights to further apart judgments. Values greater than 0.75 are considered an "excellent agreement" [33, p. 609], and in our analysis, comparing scores over all stories examined, we obtained a $\hat{\kappa}_w = 0.913$.

Empathy Component	**Dimension**
Sharing (Emotional/Affective)	Displays feeling another's emotional state or their mood being altered by others (Individual or group level)
	Displays their feelings or emotions about social injustice or cultural variations they observe (Societal level)
Caring About (Taking Action)	Displays taking action, comforting, or putting effort into their social actions, relationships, and/or activities with others (Individual or group level)
	Displays taking action or community engagement to bring about change (Societal level)
	Displays a solution or creating a potential solution that considers the needs of others and their worldviews (Can be any level)
Thinking About (Cognitive)	Displays taking stock or reflecting on their own feelings, knowledge, beliefs, values, and perspectives as they relate to others' (Personal level)
	Displays understanding others' feelings, knowledge, beliefs, values, and perspectives (Individual or group level)
	Displays understanding or consideration of community impacts, civic consequences, and/or social justice factors from different perspectives (Societal level)

Table 2: External Evaluation of Empathy Rubric (EEER) [31] dimensions described for each component of Zaki's model of empathy

4.3 Data Analysis

Data was cleaned and analyzed in Excel and using R (version 4.2.1) in RStudio (version 2022.07.1-554). In the evaluation conducted, the score for each empathy component assessed with the EEER was treated like an average, defined as:

$$score\ for\ empathy\ component = \frac{\sum scores\ within\ component}{\#\ of\ dimensions\ for\ component}$$

To compare the scores of each prompt, we described the score for each empathy component individually as well as for the overall component. The normality of each component was checked with Shapiro-Wilk tests ($\alpha = 0.05$), and given that it indicated the distribution was not normal, we utilized Kruskal Wallis tests to compare the means from each prompt. Then each prompt was compared using a post-hoc Dunn's test, employing a Bonferroni-corrected α = 0.0083, to explore the mean ranks of each pair and determine if they were significantly different.

We sought to further expand on the pilot study conducted on the EEER rubric [31] to assess the concurrent validity of how well the EEER might compare to the IRI. We explored the scores of each IRI subscale (PD, PT, and EC) relative to the corresponding component of empathy (sharing, thinking about, and caring about) from Zaki's model. We rated these and used rescaling to convert the scale from the EEER with the quantities from the IRI subscales so they had the same upper and lower limits. This entailed using the equation:

$$Y = (\frac{X - X_{min}}{X_{range}})n = (\frac{student\ score\ for\ empathy\ component - 0}{total\ possible\ score\ for\ empathy\ component})28$$

In this equation, the "28" represents the maximum possible score that could be attained on an IRI subscale. The "total possible score for empathy component" refers to the counts accumulated for an empathy component across all rated assignments multiplied by 3, the highest score possible when rated using the EEER. Since Shapiro-Wilk tests (α = 0.05) indicated that the data was normally distributed, we utilized Pearson's correlation coefficient (r) to explore the relationship between scores on the EEER and IRI.

4.4 Reflexive Process

In acknowledgement of the fact that the researchers involved in an investigation can impact decisions made and outcomes, we want to be transparent about the factors that may influence the work presented [34]. The second and third authors were both involved in the creation of the course and have both served as instructors across multiple semesters. While the first author has not been an instructor for the class, she did observe the course for a full semester. As such, they were all familiar with the content and types of responses typical of the prompts.

In addition, the first and second authors led the design of the research, rating analysis, and manuscript writing. They developed and validated this rubric previously [31]. Accordingly, they were familiar with the categorizations and scale and had practice applying the EEER to other artifacts as well.

Before evaluating each story prompt, they rated one sample submission together, discussing their interpretation of how it may apply to the context. While an individual could use the EEER alone

D3: Explore Success					
Empathy Component	**Dimension**	**Mean Dimension**	**Standard Deviation Dimension**	**Mean Component**	**Standard Deviation Component**
Sharing (Emotional/ Affective)	Displays feeling another's emotional state or their mood being altered by others (Individual or group level)	1.86	0.94	1.05	1.18
	Displays their feelings or emotions about social injustice or cultural variations they observe (Societal level)	0.23	0.65		
Caring About (Taking Action)	Displays taking action, comforting, or putting effort into their social actions, relationships, and/or activities with others (Individual or group level)	1.68	1.25	1.23	1.31
	Displays taking action or community engagement to bring about change (Societal level)	0.91	1.27		
	Displays a solution or creating a potential solution that considers the needs of others and their worldviews (Can be any level)	1.09	1.34		
Thinking About (Cognitive)	Displays taking stock or reflecting on their own feelings, knowledge, beliefs, values, and perspectives as they relate to others' (Personal level)	2.18	0.73	1.29	1.20
	Displays understanding others' feelings, knowledge, beliefs, values, and perspectives (Individual or group level)	1.23	1.11		
	Displays understanding or consideration of community impacts, civic consequences, and/or social justice factors from different perspectives (Societal level)	0.45	1.06		

if employing it for a course, for the purposes of our research, we wanted to ensure multiple perspectives were considered in the evaluation to allow for variations in interpretation. We also want to note that the third author was invited to transparently provide critical questioning on these efforts.

5 Results

5.1 ***RQ1:*** *How do unique story prompts elicit different aspects of empathy from Zaki's model, including sharing, thinking about, and caring about others?*

As described, the stories submitted around the prompts were rated using the EEER. We present the results for each artifact as defined by the mean score and standard deviation within each dimension and across dimensions to evaluate the overall empathy component. Each deliverable (D3, D5, D12, and DFinal) is presented separately to allow for comparison of the empathy aspects observed in stories crafted around each prompt.

We also evaluated each component of empathy using Kruskal-Wallis tests, as described in Table 4. There was a significant difference in the scores for each story prompt in terms of: sharing, $H(3) = 11.84$, $p < 0.01$; caring about, $H(3) = 30.36$, $p < 0.001$; and thinking about, with $H(3) = 20.92$, $p < 0.001$. In addition, post-hoc Dunn's tests using a Bonferroni-corrected alpha of 0.0083 were employed to compare the differences in mean ranks between each pair of prompts (Table 5). Only the significant pairs are reported in the table.

5.2 ***RQ2:*** *How do biomedical engineering students self-perceptions of empathy correspond to external evaluations of empathy from stories shared?*

To evaluate internal, self-perceived empathy on the IRI relative to externally evaluated empathy, we used adjusted scores for each empathy component, rescaled to align with the IRI subscales. The breakdown of the students' scores is presented in Figure 2. The red line illustrates the relationship observed in the data.

D5: Confronting/Responding to Failure					
Empathy Component	**Dimension**	**Mean Dimension**	**Standard Deviation Dimension**	**Mean Component**	**Standard Deviation Component**
Sharing (Emotional/ Affective)	Displays feeling another's emotional state or their mood being altered by others (Individual or group level)	1.05	1.23	0.70	1.11
	Displays their feelings or emotions about social injustice or cultural variations they observe (Societal level)	0.35	0.88		
Caring About (Taking Action)	Displays taking action, comforting, or putting effort into their social actions, relationships, and/or activities with others (Individual or group level)	0.85	1.18	0.40	0.89
	Displays taking action or community engagement to bring about change (Societal level)	0.00	0.00		
	Displays a solution or creating a potential solution that considers the needs of others and their worldviews (Can be any level)	0.35	0.81		
Thinking About (Cognitive)	Displays taking stock or reflecting on their own feelings, knowledge, beliefs, values, and perspectives as they relate to others' (Personal level)	1.60	0.88	0.85	1.09
	Displays understanding others' feelings, knowledge, beliefs, values, and perspectives (Individual or group level)	0.90	1.25		
	Displays understanding or consideration of community impacts, civic consequences, and/or social justice factors from different perspectives (Societal level)	0.05	0.22		

D12: My Future Perfect					
Empathy Component	**Dimension**	**Mean Dimension**	**Standard Deviation Dimension**	**Mean Component**	**Standard Deviation Component**
Sharing (Emotional/ Affective)	Displays feeling another's emotional state or their mood being altered by others (Individual or group level)	1.70	1.17	1.23	1.29
	Displays their feelings or emotions about social injustice or cultural variations they observe (Societal level)	0.75	1.25		
Caring About (Taking Action)	Displays taking action, comforting, or putting effort into their social actions, relationships, and/or activities with others (Individual or group level)	1.85	1.23	1.57	1.31
	Displays taking action or community engagement to bring about change (Societal level)	1.40	1.39		
	Displays a solution or creating a potential solution that considers the needs of others and their worldviews (Can be any level)	1.45	1.32		
Thinking About (Cognitive)	Displays taking stock or reflecting on their own feelings, knowledge, beliefs, values, and perspectives as they relate to others' (Personal level)	2.50	0.76	1.78	1.25
	Displays understanding others' feelings, knowledge, beliefs, values, and perspectives (Individual or group level)	1.50	1.28		
	Displays understanding or consideration of community impacts, civic consequences, and/or social justice factors from different perspectives (Societal level)	1.35	1.35		

DFinal: About Me					
Empathy Component	**Dimension**	**Mean Dimension**	**Standard Deviation Dimension**	**Mean Component**	**Standard Deviation Component**
Sharing (Emotional/ Affective)	Displays feeling another's emotional state or their mood being altered by others (Individual or group level)	2.35	0.79	1.68	1.28
	Displays their feelings or emotions about social injustice or cultural variations they observe (Societal level)	1.00	1.32		
Caring About (Taking Action)	Displays taking action, comforting, or putting effort into their social actions, relationships, and/or activities with others (Individual or group level)	1.94	1.14	1.35	1.29
	Displays taking action or community engagement to bring about change (Societal level)	1.12	1.32		
	Displays a solution or creating a potential solution that considers the needs of others and their worldviews (Can be any level)	1.00	1.27		
Thinking About (Cognitive)	Displays taking stock or reflecting on their own feelings, knowledge, beliefs, values, and perspectives as they relate to others' (Personal level)	2.82	0.39	1.76	1.34
	Displays understanding others' feelings, knowledge, beliefs, values, and perspectives (Individual or group level)	1.24	1.35		
	Displays understanding or consideration of community impacts, civic consequences, and/or social justice factors from different perspectives (Societal level)	1.24	1.35		

Table 3: Scores for each prompt in terms of the dimensions that define them and the overall component

	***p*-Value**	χ^2	**Mean Rank Score**			
			D3	D5	D12	DFinal
Sharing (Emotional/Affective)	**	11.84	77.23	64.00	81.94	97.81
Caring About (Taking Action)	***	30.36	122.42	82.24	142.87	129.74
Thinking About (Cognitive)	***	20.92	112.95	90.80	138.60	136.95

$^{**}p < 0.01$; $^{***}p < 0.001$

Table 4: Kruskal-Wallis H test results for each empathy component

	pair	**Mean Rank difference**	**Z**	**SE**	**p-value**
Sharing (Emotional/Affective)	D5-DFinal	-33.81	3.40	9.93	***
Caring About (Taking Action)	D3-D5	40.18	3.56	11/30	***
	D5-D12	-60.63	5.24	11.57	***
	D5-DFinal	-47.49	3.94	12.07	***
Thinking About (Cognitive)	D5-D12	-47.80	4.00	11.95	***
	D5-DFinal	-46.15	3.70	12.47	***

$^{***}p < 0.001$

Table 5: Comparison results from post-hoc Dunn's test to compare pairs of artifacts each empathy component

Results of the Pearson's correlation coefficient indicated that there is a non-significant very small negative relationship between Sharing and PD, ($r(18) = .286$, $p = .222$). Results of the Pearson's correlation coefficient indicated that there is a non-significant very small positive relationship between Caring and EC, ($r(18) = .0995$, $p = .676$). Meanwhile, results of the Pearson's correlation coefficient indicated that there is a significant large positive relationship between Thinking About and PT, ($r(18) = .693$, $p < .001$).

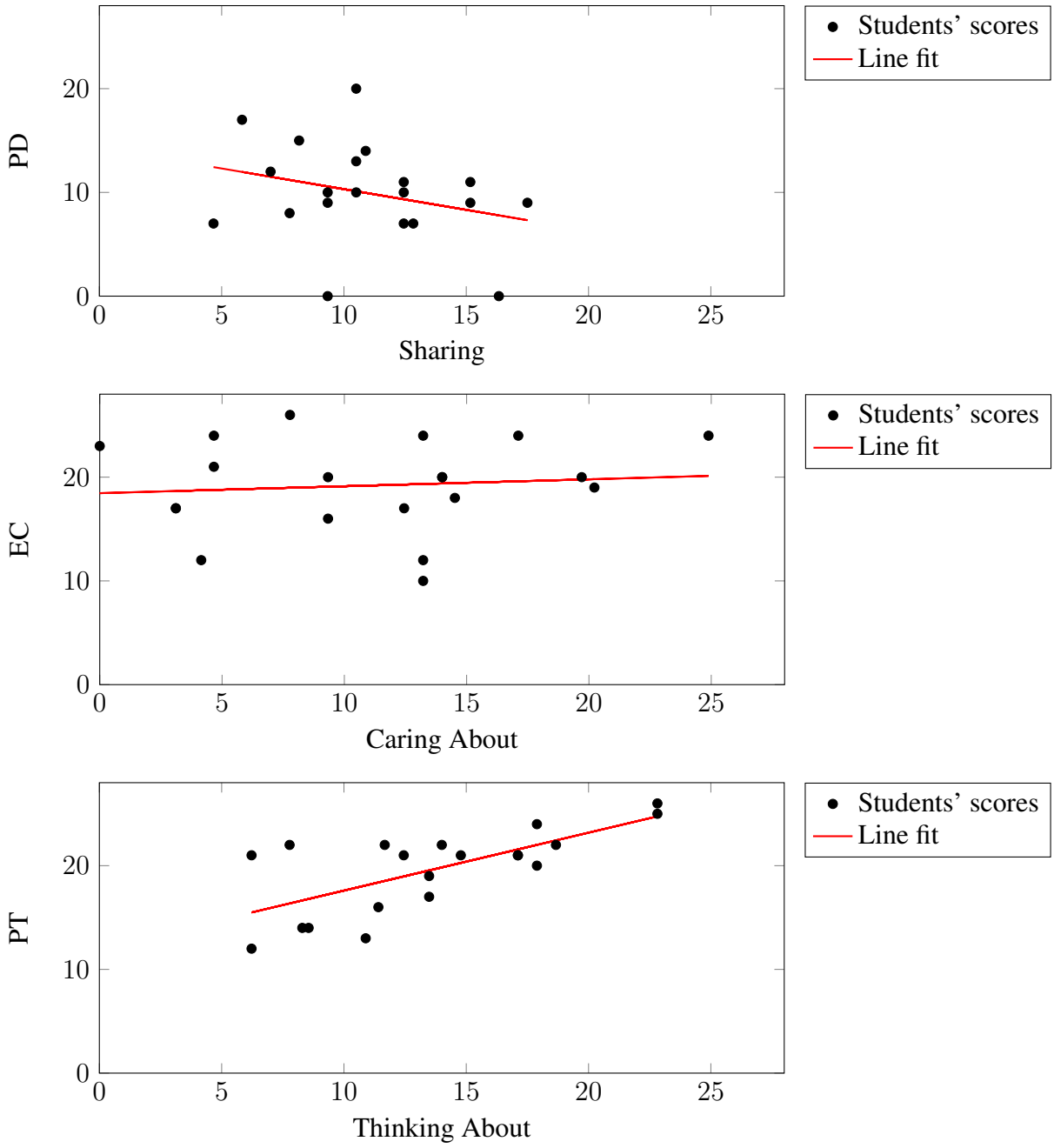

Figure 2: Students scores from each aspect of empathy rated by the EEER relative to their self-reported scores on the IRI

6 Discussion

6.1 ***RQ1:*** *How do unique story prompts elicit different aspects of empathy from Zaki's model, including sharing, thinking about, and caring about others?*

We employed the EEER rubric to assess aspects of empathy observed in stories submitted to specific prompts. As described in Table 4, there were significant differences for each component of empathy based on the topic. This aligns with other literature [35] describing that using varied pictorial prompts may impact performance in narrative development. The post-hoc Dunn's tests in Table 5 provide further insight into which prompt pairs had a significant mean rank difference. Below, we first describe the pair of D5 (Confronting/Responding to Failure) and DFinal (About Me), since it was significant for all three components described by Zaki's model (sharing, caring about, and thinking about). We then describe each component of empathy separately, before summarizing the conclusions of this RQ.

Comparing D5-DFinal: Although we cannot make definitive assumptions based on the analysis conducted, we posit the difference observed may be linked to students' consideration of failure as a personal endeavor. When exploring the scores in D5 (Table 3), we note that the averages were particularly low for societal-level dimensions. Comparatively, students' scores were highest for all three components when referring to the "individual or group level" dimensions. Our hypothesis is further supported by literature that describes how having high standards of self-evaluation tend to be linked to individuals' intolerance of failures and connections with their own self-concepts [36].

Meanwhile, students' DFinal responses more often focused on broader aspirations, which for the biomedical engineering students, typically included considering how they could impact others. This was reflected in the scores for each dimension (Table 3), where stories did include a self-focus, but also touched on societal-level change. Other scholars have described how BME is one potential field perceived as placing a higher emphasis on helping others [37, 38], a "humane field" [39, p. 1567], a perception that could entice more altruistically motivated individuals. As a discipline, it has been noted to attract students who may seek to pursue careers outside of engineering, and to lend itself to enhanced occupational pursuits in health and medicine [39, 40].

Sharing: "Sharing" was significant only for the D5-DFinal pair ($p < 0.001$). We want to call attention to the dimensions of this component reported in Table 3, in each of the prompts. In all cases, affective descriptions most often manifested as feeling another's emotional state or their mood being altered by others at the individual and group level. The prompts applied were much less likely to present as broader societal-level emotions. While this is not to say these prompts are incapable of doing so, we merely want to point out that other prompts such as "Develop a story about social injustice" or something similar might elicit more of this dimension than those examined in this study.

Caring About: Pairwise comparisons using Dunn's test indicated that D3 scores were observed to be significantly different from those of D5 in terms of "caring about" ($p < 0.001$). When looking at Table 3, the means are higher at all levels of the dimensions. Given that exploring success may be described as having worked through an obstacle, it may be unsurprising that this could involve creating a potential solution to do so. Problem solving competence has been linked with new product design and development success [41, 42]. Although not all students described this in

terms of the needs of others and their worldviews, often accomplishment was linked with taking action towards another or others. Relatively, failure was often self-focused and articulated in terms of academics, e.g., receiving a bad grade or fears about not passing a course.

For "caring about," we also observed a significant difference between D5-D12 ($p < 0.001$). Similar to what we observed with D12, thinking about students' "Future Perfect" lent itself more towards envisioning students in a broader context. This occurred across all dimensions, as the students' articulated a hypothetical future that often involved careers or taking action towards having an impact on a smaller scale, with an individual or group. We postulate that the difference observed may further support inclinations to have an impact in their idealized future, as students' described scenarios where they engaged in activities to positively bring about change for others. This aligns with the career advice for bioengineering/biomedical engineering students proposed by Abu-Faraj, which suggests it "begins with a passion nurtured with a decisive aptitude, augmented with a keen vision, strategic planning, and careful design[...] [39, p. 1565].

Thinking About: The component of "thinking about" was also significantly lower for D5 than D12 ($p < 0.001$) or, as already described, DFinal. These differences were strongly present in individual thinking and personal reflection about goals and desires, as illustrated in Table 3. Both prompts encouraged students to think about themselves, but doing so led to stories that often considered their influence on a larger scale. When looking at the cognitive aspect's personal dimension, the average rating for all students from the EEER analysis was close to the exemplary score of 3, with a mean of 2.50 for D12 and 2.282 for DFinal. These scores speak to how these prompts may extend beyond merely making sense of events as students contemplate their aspirations.

Summary: While we encourage additional follow up studies to further explore how prompts may impact the story crafting process, we do see from this investigation that the choice of prompt can impact the resulting stories. Accordingly, the framing of prompts in storytelling can influence the aspects of empathy that are observed. Although each individual may have their own experiences and goals, it is important for educators to consider the kinds of prompts posed depending on the desired learning outcomes.

6.2 ***RQ2:*** *How do biomedical engineering students self-perceptions of empathy correspond to external evaluations of empathy from stories shared?*

As scholars have articulated in other contexts, self-reports may be inadequate and do not always align with scores from external evaluation [43, 44]. We compared internally-reported aspects of empathy described by Davis' IRI to scores externally rated in stories shared by the EEER. Although this was only a preliminary assessment, given the number of students in the analysis, we did observe a very small relationship between Sharing and PD, as well as Caring and EC. While it is promising that these pairs follow similar patterns, from the perspective of validating the EEER, it was not significant, indicating more studies may be needed to further determine the relationships. However, a lack of significance demonstrates that students' perceptions of these components may also not align with what presents in artifacts they produce.

Something to note is that if instructors were to incorporate the EEER into story feedback, it may make students more aware of how their empathy is perceived, leading to greater alignment in scores. Yet, this could also yield more deliberate attempts to include specific anecdotes towards this goal, something that must be taken into account. There are some additional factors that may

have influenced the lack of significance between these two instruments and the students' self-reported empathy compared to that observed externally.

Although the instruments are intended to complement each other, we do acknowledge that differences can arise from empathy externally assessed relative to that which is self-reported. Self-reported affective or cognitive states for subjective constructs have been described in other assessments as "transient," and potentially influenced by situational contexts [45]. The wording used between the two instruments is not the same, and the context of broadly self-reporting empathy is different than assessing it through specific coursework. Furthermore, apart from the small number of students reporting, self-perceptions of PD and EC may be better observed in other types of artifacts or in stories crafted around additional prompts.

Relative to Sharing-PD and Caring-EC, a significant large positive relationship was observed between Thinking About and PT (($r(18) = .693$, $p < .001$), showing that both measure a similar construct and alignment in students' self-reports and empathy observed in relation to the prompts described. It is not possible to directly observe another's cognitive processes as is feasible with direct actions or behaviors [46]. However, the use of storytelling represents one potential way for instructors and researchers to gain insight. As we demonstrated, applying the EEER to stories submitted could help to quantify aspects of empathy around "thinking about," and can do so on multiple levels, including the personal, individual or group, and/or societal.

7 Limitations

Our investigation was limited in several ways. First, this study focused on delving into a lot of stories on a small number of students in a single course. Since sharing around prompts was graded, students may have been differentially motivated. As described by demand characteristics bias, subjects may form ideas about what they think the instructor wants to see and subconsciously adjust the narratives shared to fit that interpretation. Furthermore, the IRI relies on self-reported data, and students' answers may have tried to make themselves appear more favorable or socially desirable. Also, the stories and scores examined were only reflective of those participants willing to allow us to evaluate their artifacts, which may lead to differences in the responses of those not included. Moreover, the students included in this analysis came from a single institution over the span of two semesters, and respondents elsewhere may have interpreted the prompts and crafted stories around them differently. Future research should consider expanding to include additional students and prompts to further explore their impact. It would also be interesting to design a longitudinal study to investigate how SDL may impact students throughout their program as they work towards a degree.

In addition, correlation does not imply causation. We were not seeking to claim that storytelling directly induces empathy, but merely to understand how aspects may appear in response to different prompts. However, to better understand the relationship and a potential mechanism for how SDL may cultivate empathy, before-and-after tests or additional qualitative studies could delve further into examining the possible impact.

8 Conclusions

In this work, we presented an overview of SDL and its application in the course "The Art of Telling Your Story." We explored how the application of different prompts can elicit varying components and dimensions of empathy—including sharing, caring about, and thinking about

others—in stories. We observed that certain prompts, specifically "about me" and "my future perfect," may yield depictions of BME students' broader goals, which frequently depict scenarios involving helping another, others, and/or society.

This study also compared internally and externally assessed empathy. We provided evidence for a relationship between the IRI and the EEER, although further studies are needed. In particular, there was a significant large positive relationship between "thinking about" and the PT subscale when comparing the scores on the EEER to self-reported IRI scores. Given that it can typically be hard to report on another's thought processes, this finding suggests that SDL can be a useful means of eliciting more of this type of empathy and being able to externally evaluate its presence using the EEER. Going forward, we encourage others to consider the value of SDL and how specific prompts may help students redefine their experiences and articulate their thinking.

References

[1] P. Parrish, "Design as Storytelling," *TechTrends*, vol. 50, no. 4, pp. 72–82, 2006.

[2] J. Walther, M. A. Brewer, N. W. Sochacka, and S. E. Miller, "Empathy and engineering formation," *Journal of Engineering Education*, vol. 109, no. 1, pp. 11–33, 2020.

[3] S. J. Lunn, C. L. Bell-Huff, and J. M. Le Doux, "Cultivating Inclusivity: A Systematic Literature Review on Developing Empathy for Students in STEM Fields," in *Collaborative Network for Engineering and Computing Diversity (CoNECD)*, February 2022.

[4] J. M. LeDoux and J. Shaffer, "Learn the Art of Telling Your Story (& How Story-Driven Learning Promotes Entrepreneurial Mindset)," 2020, KEEN National Conference. [Online]. Available: https://engineeringunleashed.com/card/414

[5] P. J. Manney, "Empathy in the Time of Technology: How Storytelling is the Key to Empathy," *Journal of Evolution & Technology*, vol. 19, no. 1, 2008.

[6] R. Hibbin, "The psychosocial benefits of oral storytelling in school: developing identity and empathy through narrative," *Pastoral Care in Education*, vol. 34, no. 4, pp. 218–231, 2016.

[7] R. Rose, S. Chakraborty, P. Mason-Lai, W. Brocke, S. A. Page, and D. Cawthorpe, "The storied mind: A meta-narrative review exploring the capacity of stories to foster humanism in health care," *Journal of Hospital Administration*, vol. 5, no. 1, pp. 52–61, 2016.

[8] D. Ketelle, "Introduction to the Special Issue: What Is Storytelling in the Higher Education Classroom?" *Storytelling, Self, Society*, vol. 13, no. 2, pp. 143–150, 2017.

[9] D. V. Anderson, "Storytelling—The Missing Art in Engineering Presentations," *IEEE Signal Processing Magazine*, vol. 28, no. 2, p. 105, 2011.

[10] K. L. Morgan, C. L. Bell-Huff, J. Shaffer, and J. M. LeDoux, "Story-driven learning: A pedagogical approach for promoting students' self-awareness and empathy for others," in *2021 American Society for Engineering Education (ASEE) Virtual Annual Conference Content Access*, 2021.

[11] S. J. Lunn and C. L. Bell-Huff, "What Story Do You Want to Tell? Developing Empathy in

Engineering Students through an Extra-Curricular Narrative Sharing Experience," in *2022 American Society for Engineering Education (ASEE) Annual Conference*, June 2022.

[12] C. Bell-Huff, J. M. LeDoux, and J. Shaffer, "The Art of Telling Your Story: A Course to Help Students See Themselves as Entrepreneurially Minded," 2021, KEEN Card. [Online]. Available: https://engineeringunleashed.com/card/2861

[13] J. Zaki, *The War for Kindness: Building Empathy in a Fractured World*. Crown, 2019.

[14] J. B. Hunsdahl, "Concerning Einfühlung (empathy): A Concept Analysis of its Origin and Early Development," *Journal of the History of the Behavioral Sciences*, vol. 3, no. 2, pp. 180–191, 1967.

[15] J. Koss, "On the Limits of Empathy," *The Art Bulletin*, vol. 88, no. 1, pp. 139–157, 2006.

[16] M. Nowak, "The Complicated History of Einfühlung," *Argument: Biannual Philosophical Journal*, vol. 1, no. 2, pp. 301–326, 2011.

[17] A. Smith, *The Theory of Moral Sentiments*. Kapaau, HI: Gutenberg Publishers, 2011.

[18] H. Spencer, *The Principles of Psychology*. London: Williams and Norgate, 1870.

[19] M. H. Davis, "A Multidimensional Approach to Individual Differences in Empathy," *JSAS Catalog of Selected Documents in Psychology*, vol. 10, p. 85, 1980.

[20] J. S. Coke, C. D. Batson, and K. McDavis, "Empathic Mediation of Helping: A Two-Stage Model," *Journal of Personality and Social Psychology*, vol. 36, no. 7, pp. 752–766, 1978.

[21] R. J. Iannotti, "The Elements of Empathy," 1979.

[22] S. Konrath and D. Grynberg, *The Positive (and Negative) Psychology of Empathy*. Nova Science Publishers Inc, 2016.

[23] J. Strobel, J. Hess, R. Pan, and C. A. Wachter Morris, "Empathy and care within engineering: Qualitative perspectives from engineering faculty and practicing engineers," *Engineering Studies*, vol. 5, no. 2, pp. 137–159, 2013.

[24] J. Walther, S. E. Miller, and N. W. Sochacka, "A Model of Empathy in Engineering as a Core Skill, Practice Orientation, and Professional Way of Being," *Journal of Engineering Education*, vol. 106, no. 1, pp. 123–148, 2017.

[25] N. Abu-Mulaweh, W. Oakes, and J. Hess, "Empathy Development in Community-Engagement Course," in *2022 ASEE Annual Conference & Exposition*, 2022.

[26] N. W. Sochacka, D. A. Delaine, T. G. Shepard, and J. Walther, "Empathy Instruction through the Propagation Paradigm: A Synthesis of Developer and Adopter Accounts," *Advances in Engineering Education*, vol. 9, no. 1, 2021.

[27] J. L. Hess, J. Beever, C. B. Zoltowski, L. Kisselburgh, and A. O. Brightman, "Enhancing engineering students' ethical reasoning: Situating reflexive principlism within the SIRA framework," *Journal of Engineering Education*, vol. 108, no. 1, pp. 82–102, 2019.

[28] R. Shultz Colby, "Embodying empathy: using game design as a maker pedagogy to teach design thinking," *Technical Communication Quarterly*, pp. 1–15, 2022.

[29] É. E. Villalba, A. L. S. M. Azócar, and F. A. Jacques-García, "State of the art on immersive virtual reality and its use in developing meaningful empathy," *Computers & Electrical Engineering*, vol. 93, p. 107272, 2021.

[30] M. Sansoni, S. Bartolotta, A. Gaggioli, and G. Riva, "Can you Empathize with Me? Development of a 360° Video-Training to Enhance Residents' Empathic Abilities," in *2022 IEEE International Conference on Metrology for Extended Reality, Artificial Intelligence and Neural Engineering (MetroXRAINE)*. IEEE, 2022, pp. 211–216.

[31] S. J. Lunn, C. L. Bell-Huff, and J. M. Le Doux, "Establishing a Rubric to Assess Students' Empathy Development Using Artifacts from Biomedical Engineering Courses." IEEE, 2022.

[32] M. H. Davis, "Measuring Individual Differences in Empathy: Evidence for a Multidimensional Approach," *Journal of personality and social psychology*, vol. 44, no. 1, p. 113, 1983.

[33] J. L. Fleiss, B. Levin, and M. C. Paik, *Statistical Methods for Rates and Proportions*, 3rd ed. John Wiley & Sons, 2003.

[34] J. P. Martin, R. Desing, and M. Borrego, "Positionality statements are just the tip of the iceberg: Moving towards a reflexive process," *Journal of Women and Minorities in Science and Engineering*, vol. 28, no. 4, 2022.

[35] N. De Jong and M. L. Vercellotti, "Similar prompts may not be similar in the performance they elicit: Examining fluency, complexity, accuracy, and lexis in narratives from five picture prompts," *Language Teaching Research*, vol. 20, no. 3, pp. 387–404, 2016.

[36] T. Thompson, H. Davis, and J. Davidson, "Attributional and affective responses of impostors to academic success and failure outcomes," *Personality and Individual differences*, vol. 25, no. 2, pp. 381–396, 1998.

[37] G. Potvin, C. McGough, L. Benson, H. J. Boone, J. Doyle, A. Godwin, A. Kirn, B. Ma, J. Rohde, M. Ross, and D. Verdín, "Gendered Interests in Electrical, Computer, and Biomedical Engineering: Intersections With Career Outcome Expectations," *IEEE Transactions on Education*, vol. 61, no. 4, pp. 298–304, 2018.

[38] N. Quadlin, "From Major Preferences to Major Choices: Gender and Logics of Major Choice," *Sociology of Education*, vol. 93, no. 2, pp. 91–109, 2020.

[39] Z. O. Abu-Faraj, "Career Development in Bioengineering/Biomedical Engineering: A Student's Roadmap," in *2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. IEEE, 2008, pp. 1564–1567.

[40] A. D. Patrick, "A Quantitative Study of Intended Post-Graduation Plans of Undergraduate Biomedical Engineering Students: Assessing Self-Efficacy, Value, and Identity Beliefs," Ph.D. dissertation, The University of Texas at Austin, 2020.

[41] K. Atuahene-Gima and Y. Wei, "The Vital Role of Problem-Solving Competence in New Product Success," *Journal of Product Innovation Management*, vol. 28, no. 1, pp. 81–98, 2011.

[42] J. S. Reel, "Critical Success Factors In Software Projects," *IEEE Software*, vol. 16, no. 3, pp. 18–23, 1999.

[43] H. Blok, P. Sleegers, and S. Karsten, "Looking for a balance between internal and external evaluation of school quality: Evaluation of the SVI model," *Journal of education policy*, vol. 23, no. 4, pp. 379–395, 2008.

[44] F.-J. Tsai and R. Katz, "Measuring Global Health Security: Comparison of Self-and External Evaluations for IHR Core Capacity," *Health Security*, vol. 16, no. 5, pp. 304–310, 2018.

[45] W. Pavot and E. Diener, "The Affective and Cognitive Context of Self-Reported Measures of Subjective Well-Being," *Social Indicators Research*, vol. 28, no. 1, pp. 1–20, 1993.

[46] S. Afroogh, A. Esmalian, J. Donaldson, and A. Mostafavi, "Empathic Design in Engineering Education and Practice: An Approach for Achieving Inclusive and Effective Community Resilience," *Sustainability*, vol. 13, no. 7, p. 4060, 2021.