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RESEARCH ARTICLE

Exploring the Use of Resume Reviews to Understand Skill Sets Valued in Biomedical Engineers by Employers

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Abstract

The breadth of opportunities in biomedical engineering (BME) creates both a diversity of career options for students pursuing the degree and a potential hurdle in communicating the relevance of their skills when applying for specific jobs. This conundrum has driven research efforts seeking to understand what is valued by BME employers. Our work explored this area of need through an analysis of researcher-designed resumes (DRs) based on skills potentially of interest to BME recruiters in industry and academia. DRs were distributed to potential employers through an online survey asking about their perspectives on the quality of a subset of four DRs based on their indicated area of expertise. We performed a quantitative and qualitative analysis of 12 industry and 6 academic responses and compared our results to existing BME resume evaluation rubrics. Our results confirm a quantitative alignment between existing BME resume rubrics and employer's perceptions which was previously unexplored. Qualitative results pointed toward (1) the importance of how experiences are represented as an important differentiator in resume reviews, (2) the acknowledgment from reviewers that resumes are only one step in a job application, and (3) specific similarities and differences in the skills that academic and industry employers look for in BME resumes. Our work provides validity evidence from employer perspectives to support the use of existing resume guidance tools in BME. Our qualitative data analysis expands that guidance by making recommendations for additional tools to craft resumes that clearly communicate the relevant experiences of an applicant.

Keywords Resume · Academia · Industry · Professional development

Introduction

Applicant-generated summaries of job qualifications on resumes are frequently assessed in the first stage of an employer's application screening process [1–3]. The primary purpose of resume screening is to help employers select quality applicants for interviews, commonly the next stage of an employer's candidate search [4]. In order to communicate the appropriate information in a succinct and readable way, resumes are often structured as 1–2 page documents that signal specific job qualities of an applicant in separate sections (e.g., education, prior work experiences, other qualifications), but these documents may also signal non-job-related information (e.g., demographics) about an applicant unintentionally [1].

Because resumes are commonly used as a first-stage screening tool in employment searches, they can strongly impact the processes through which companies hire employees. However, studies that have sought to explore and explain the features of what makes up a high-quality resume have produced mixed results. In addition, many studies have established that biases in resume review practices exist and span disciplinary and national boundaries. These biases have been linked to differences in how recruiters interview candidates based on first impressions of a resume, homogeneity in the workplace due to recruiters' tendency to select applicants with similar traits to existing employees [1], and trends in interview offers that disservice non-white, non-male, and immigrant applicants [1, 4–6].

Given evidence that biases in resume review processes are impacting hiring practices, researchers have begun to explore strategies to mitigate these biases. These strategies include changes to screening practices like anonymous

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screening, enhanced personalization of application materials, standardized application forms, as well as changes to selecting, training, accountability of human decision makers, and the addition of review technology with algorithms to assist in the hiring process [1, 6, 7]. As the ratio of applicants to available jobs increases, more and more large companies are leveraging technology to identify the promising candidates by scanning resumes for programmed keywords, former employers, length of experience, and education [7]. This practice means that it is critical for both employers and applicants to understand what a good match might look like to ensure that the algorithms do not prematurely eliminate promising applicants from the pool at the resume review stage. This work requires an in-depth exploration of employer expectations and review processes that most resume studies have not yet accomplished.

Our study is situated in the context of undergraduate biomedical engineering (BME) and seeks to explore the roles of resumes in communicating the alignment of specific skills and experiences for the broad range of careers that entry-level BME graduates can secure. To do so, we drew on previous resume studies in engineering [18] to design a set of resumes and sought quantitative and qualitative feedback from professionals in the academic, healthcare, and industry sectors of BME practice. In this paper, we explored the alignment of reviewer interpretations of researcher-designed resumes with previously established BME resume rubrics.

Background

Engineering educators have discussed the importance of resumes in career searches of engineering students for many years. In general, discussions have focused on three key areas: the need for general guidance for students writing resumes, the importance of capturing engineering discipline-specific expectations in resumes, and the promise of resumes as an engineering professional development tool.

Development of General Resume Guidance

Some universities have begun to develop and leverage career services offices to help support students' resume development in preparation for their careers. While these services are beneficial to the students using them, they often require students to seek out the resources themselves and are unable to serve all students at the institution. At the same time, engineering educators have discussed the need for formal training for students on writing high-quality resumes, but acknowledge overfilled curricula as a common barrier preventing the addition of resume training materials to the formal requirements of engineering degrees [8, 9]. Despite the many hurdles to training students on resume creation, engineering educators have worked to create and implement resources for students to improve their resumes within courses. Approaches include having students create and revise a resume as a part of a foundations course [9], encouraging students to talk to multiple sources of information (e.g., disciplinary experts, technical communication experts) to understand best practices for building a resume [10], or creating resume checklists that are co-authored with career services offices [8]. Much of the guidance provided in these course-based training efforts focus on improving the communication strategies of students who are crafting their resumes. Indeed, well-constructed resumes with few grammar errors have been identified as a strong preference for some resume reviewers [11] and may be an indicator of preferred entry-level engineering communication skills that are common in job postings [12], including in BME [2].

Other engineering professionals have also created guidance on writing high-quality resumes to aid engineering educators and students. This includes Harper's [13] chapter on Resume Review that, along with course-derived guidance resources, focuses on assisting students in identifying the content sections that should be covered in a resume and emphasizes the importance of formatting strategies for communicating the skills of the applicant. However, even within the few articles that do give advice on crafting compelling engineering resumes, there is conflicting advice on the content (e.g., whether to include an objective statement [8] or not [13]) and on the formatting of resumes (e.g., where the education section belongs on a resume [13]). Furthermore, many of the recommendations crafted in these guidelines are informed by recommendations from career centers that, because they serve all majors at an institution, do not have the capacity to develop materials that capture differences in skill preference, style, etc., that occur in each engineering discipline to account for best practices that would be specific to BME resume construction [12].

Characterizing Differences in Disciplinary Expectations

Beyond the basic content and formatting, a successful engineering resume must communicate the significance and relevance of the skills and experiences of the applicant. Research looking into differences in perspectives among resume reviewers in different fields has shown that disciplinary differences in resume expectations and interpretations do exist [14]. As such, researchers have begun to recognize the importance of understanding disciplinary-specific requirements for quality resumes and have started to ask questions about what the most sought after skills and experiences on an engineering resume are. One research team, Berdanier, Fillenworth, and McCall, leveraged the Engineering Competency Model [15] put forth by the American Association

of Engineering Societies (AAES) to explore engineering resume quality quantitatively [12, 16, 17]. They used the six tiers of the AAES Engineering Competency Model (refer to the first column in Table 1) to create a rubric that assigns a score that reflects the resume quality based on the engineering disciplinary discourse present in the resumes. While the Engineering Competency Model encompassed many of the skills necessary to capture industry skill sets, Berdanier, Fillenworth, and McCall added skills that would better capture the skills and experiences of engineering professionals outside of industry roles. Through their studies, Berdanier, Fillenworth, and McCall found that applying the rubric allowed them to distinguish between quality of resumes regardless of the level of the experience (e.g., status of current role, years in career) within each resume (refer to the second column in Table 1). Their work exemplifies the importance of accounting for disciplinary context when constructing a resume and pushes against the notion of a disciplinary agnostic, generalizable structure for successful resume construction [12, 16, 17].

Building on calls to account for engineering-specific nuances of resume construction, McCarty and Furtney [18] recently shared an approach to provide guidance for biomedical engineers. The authors stated that the motivation stemmed in part from the wide range of career paths available to BME students once they obtain a bachelor's degree. As such, McCarty and Furtney adapted the AAES rubric to provide guidance specific to three BME career sectors: healthcare, industry, and academia (Table 2). Their findings implied the usefulness of the rubrics for assessing the alignment of a resume with a specific career pathway in BME and provided recommendations for their use in helping guide students through experiences during their undergraduate programs.

Enhancing Students' Career Awareness Through Resume Creation and Review Activities

In agreement with conclusions drawn by McCarty and Furtney [18], other educators and researchers have

Table 1 AAES Engineering Competency Model [15] with Berdanier et al. additions [12]

Original AAES Competency Model	Berdanier et al. Additions
Tier 1: Personal Effectiveness Competencies (score = 1)	
Interpersonal skills; integrity; professionalism; initiative; dependability and reliability; adaptability and flexibility; lifelong learning	–
Tier 2: Academic Competencies (score = 2)	
Reading; writing; mathematics; science and technology; communication (verbal, written, visual); critical and analytical thinking; basic computer skills;	School-related research skills
Tier 3: Workplace Competencies (score = 3)	
Teamwork; client/stakeholder focus; planning and organizing; creative thinking; problem-solving and decision-making; seeking and developing opportunities and solutions; working with tools and technology; scheduling and coordinating; checking, examining, and recording; business fundamentals	(General) teaching
Tier 4: Industry-Wide Technical Competencies (score = 4)	
Foundations of engineering; design; manufacturing and construction; operations and maintenance; ethics; business, legal and public policy; sustainability and societal/environmental impact; engineering economics; quality control and quality assurance; safety; health; security and environment	General research competency; ability to write grants; publish internal reports; global competency
Tier 5: Industry/Sector Functional Areas (score = 5)	
Competencies to be specified by company representatives	Demonstration of specialized expertise; industry-specific research; teaching at university level as expert; obtain advanced degrees; obtain industry-specific funding; member of professional societies; note research advisor (vetting to professional community)
Tier 6: Job-specific Competencies (score = 6)	
Occupation-specific requirements; management competencies; staffing; informing; delegating; networking; monitoring work; entrepreneurship; supporting others; motivating and inspiring; developing and mentoring; strategic planning and action; preparing and evaluating budgets; clarifying roles and objectives; managing conflict and team building; developing an organizational vision; monitoring and controlling resources	–

Table 2 Healthcare, Industry, and Academia rubrics [18] based on the AAES [15] and Berdanier et al. [12] rubrics

AAES tier	Industry rubric	Academia rubric	Healthcare rubric
Tier 1: Personal Effectiveness Competencies (score = 1)	**Add:** Volunteering	**Add:** Volunteering	–
Tier 2: Academic Competencies (score = 2)	**Add:** academic research	**Remove:** school-related research skills	**Add:** foreign language
		Add: research topic knowledge	
Tier 3: Workplace Competencies (score = 3)	–	**Remove:** business fundamentals	**Add:** patient focus, teaching
		Add: managing conflict and team building	**Modify:** [medical] business fundamentals
Tier 4: Industry-Wide Technical Competencies (score = 4)	**Add:** global competency, foreign language	**Remove:** manufacturing and construction; operations and maintenance; business, legal and public policy; engineering economics; quality control and quality assurance	**Remove:** health; security and environment
		Add: publish internal reports, global competency	**Add:** general research competency; global competency; shadowing (<1 month), volunteering in a medical establishment; working with medical tools and technology; scheduling and coordinating medical events (check-ups, surgeries, etc.)
		Modify: foundations of [science]; [experimental] design	**Modify:** Foundations of [medicine]; business, legal and public policy [regarding physicians]; quality control and quality [of care]
Tier 5: Industry/Sector Functional Areas (score = 5)	**Remove:** obtain industry-specific funding	**Move to 6:** obtain industry-specific funding; note research advisor (vetting to professional community); teaching at university level as expert; industry-specific research	**Remove:** industry-specific research; teaching at university level as expert
	Modify: Industry-specific [internships]	**Add:** general research competency; ability to write grants	**Add:** Scribing; shadowing (1–6 months); Published Literature
		Modify: Competencies to be specified by [university] representatives	**Modify:** Competencies to be specified by [medical school] representatives; obtain [medical degrees (MS, CNA, RN, etc.)]
Tier 6: Job-specific Competencies (score = 6)	-	**Modify:** Occupation-specific requirements [specifically for academic/lab settings]	**Remove:** All
		Moved from 5: obtain industry-specific funding; note research advisor (vetting to professional community); teaching at university level as expert; industry-specific research	Add: Applicant-specific requirements; high MCAT score; High GPA (3.85+); head/chief medical scribe; shadowing (>6 months)

Only additions and modifications are indicated. Bold text details what kind of change was made

discussed the usefulness of resume development activities in supporting students' integration into engineering practice [8, 12, 16]. In Anderson-Rowland and Culley's [8] work, they observed that the resume checklists and creation activities they had built into their courses not only improved students' resumes, but also assisted them in career planning. In particular, they described a process whereby resume creation helped students identify gaps between their current experiences and their future career goals. Similarly, other scholars [12, 16, 17] have described the importance of resume creation for students' ability to effectively learn the language necessary to communicate their relevant skills and understand their responsibilities in the professional workplace [12]. They also recommended having students engage with the activity of scoring their resumes with the AAES rubric early on to help students reflect on their experiences and motivate them to set or pursue their professional career goals. Given the benefits that resume creation and development offer to students, it is critical that we continue to explore better ways to guide students' resume construction in engineering.

Where Our Study Fits in the Literature

While resumes have been frequently discussed as important in professional settings broadly [1, 4–6], in engineering [12, 16, 17], and even in BME specifically [18], there is still much to learn about how resumes can impact students' career exploration and search experiences. Resume research has employed semi-experimental methodologies like field studies (i.e., submission of designed resumes to real job postings) to explore how real employers react to designed resumes [6], but because this methodology does not follow up with the employers who reviewed the resumes, it lacks important information about how the employers interpreted the explicit and implicit information presented on resumes [1]. Newer approaches, like the incentivized resume reviews described by Kessler [19] or the study on the impact of impression management tactics in resumes (i.e., defined strategies used to control the image an individual projects to others) performed by Waung et al. [20] have the advantage of collecting more detailed and specific information through surveys that allow reviewers to provide additional information on their review processes and decisions. Berdanier et al. [12] have similarly called for additional empirical resume studies, particularly ones that explore the use of the AAES model for engineering resume construction. Our study leveraged McCarty and Furtney's prior work [18] that developed BME-specific resume rubrics with the AAES model to design our own resume study that can elicit detailed information from BME professionals and explore the following research questions:

(1) What qualities, skills, and experiences are reviewers looking for in the resumes of potential BME hires?
(2) How can these qualities, skills, and experiences be represented on resumes of BME undergraduates?

Study Design

To address these questions, we designed a collection of six resumes (DRs) with varying strength and alignment to two major BME career pathways (academia and industry). The development of these DRs was informed by collected student resumes and the quantitative rubrics that McCarty and Furtney [18] created to evaluate resumes in each of three career pathways, including healthcare. Once developed, the DRs were built into a survey to gather insights into the alignment of academia and industry reviewer perspectives with the existing BME-specific rubrics. This work was reviewed and determined exempt from IRB oversight at the institution at which the study took place.

Collected Resumes

The DRs were modeled after 12 resumes that were collected from BME undergraduate students entering their fourth year at a large, R1 public university in the Midwest United States. At the time of resume collection (academic year 2019–2020), the enrollment of the university's BME program was approximately 400 students (~56% identified as female, ~16% held a marginalized racial or ethnic identity in engineering). Students contributing resumes completed degrees in one of three concentrations: bioelectrical (~11% of graduates), biochemical (~58% of graduates), or biomechanical (~31% of graduates). Of the students who contributed their resumes, 9 identified as female, 2 identified as Hispanic/Latinx, 4 identified as Asian, and 6 identified as White/Caucasian. The resumes were collected to provide examples of experiences that could be reasonably anticipated of a soon-to-be BME bachelor's degree graduate.

Rubrics

The rubrics designed by McCarty and Furtney [18] generate career pathway competency (CPC) scores that reflect the average strength and alignment of the skills represented on resumes to each of three major career pathways. On each rubric, common BME skills and experiences are organized into six tiers (Tier 1 being the weakest, Tier 6 being the strongest) based on their presumed value and relevance to academia, industry, and healthcare employers. Differences in the value of a skill across the major career paths are reflected in the different tiers in which the skills are placed on the rubrics (Table 2).

Designed Resumes

To obtain employer perspectives on the relative value of common BME skills, we created two sets of DRs (industry and academia) that each contained one DR with a high CPC score, two DRs with mid-range CPC scores, and one low CPC scoring DR according to the set's corresponding rubric (refer to Table 3 for scores). A total of six DRs (two high, three mid-, and one low quality) were created and organized into the two sets as demonstrated in Fig. 1. Acknowledging that it would be difficult to identify and collect data from individuals who make healthcare pathway employment or admission decisions, we did not include a subset of resumes targeting healthcare reviewer perspectives, which meant that a DR with strong alignment with the healthcare rubric from McCarty and Furtney [18] is not included in this work. We did, however, want to create opportunities to gather perspectives on healthcare-aligned experiences on DRs from industry and academia reviewers which we captured in the DRs of Theo Roose and Kennedy Johnson. Designed resumes can be found in Supplement 1. The high-quality resumes (John Appleseed and Tom Jefferson) were created with mostly Tier 4, 5, and some 6 skills from their corresponding rubrics to achieve the highest CPC scores in their respective resume set and represented applicants that are strongly suited for either academia or industry BME career pathways. The middle-quality DRs (Paul Revere, Kennedy Johnson, Theo Roose) contained mostly skills from Tiers 3, 4, and 5 and were intended to produce CPC scores between those of the high- and low-quality DRs in their respective sets. The Paul Revere DR contained skills that were medially associated with both industry and academia rubric skills. We also generated DRs (Theo Roose and Kennedy Johnson) that had skills that were medially related to the healthcare rubric's skills to explore how academia and industry reviewers differentially perceived a resume's potential alignment with a healthcare career. For instance, Kennedy Johnson—the DR in both healthcare and academia—contains some skills that are more aligned with healthcare (e.g., "University Hospital Volunteering Program"; healthcare rubric Tier 4, academia rubric Tier 1) and others that are more aligned with academia (e.g., "Research in Garcia Lab"; academia rubric Tier 6, healthcare rubric Tier 5). In this way, we designed the other middle-quality DRs to assess reviewers' preferences for the pathway skills that would be more aligned with skills valued in pathways outside of those in which the reviewers would be hiring for, allowing us to examine the uniqueness of skills for each pathway rubric in more depth. A single low-quality DR (Oliver Twist) was also shared between both sets and was intended to have the lowest relative CPC score in each resume set. As such, it contained more skills from Tiers 1, 2, and 3 than the other DRs.

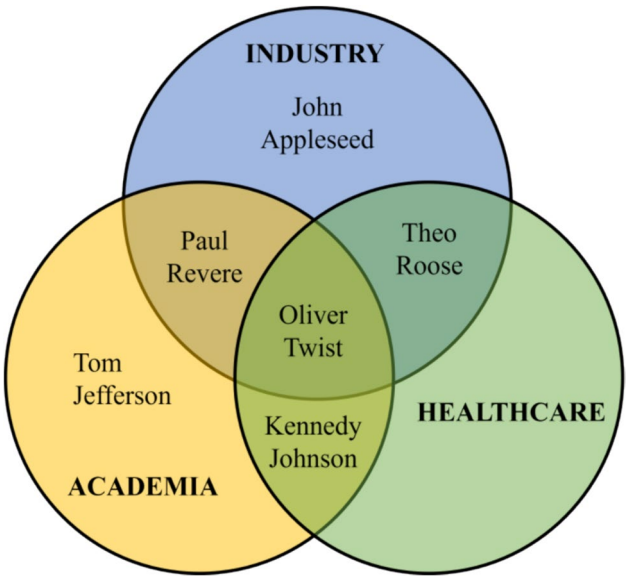

Fig. 1 Illustration of the designed resumes (DRs) that were included in the three resume sets

In addition to details corresponding to the BME-specific resume rubrics, the DRs included the name, educational institution, GPA, and degree title of the fictional applicants that they represented. To eliminate possible gender, race, or ethnicity bias during resume review [4], all six resumes were assigned white, male presenting names resembling those of prominent figures (real and fictional) in Western history and literature (Table 3). Similarly, the academic credentials on

Table 3 DR intended alignment and averaged Career Pathway Competency (CPC) scores, as evaluated by the first and second authors based on previously developed BME resume rubrics [18]

	Intended alignment	Healthcare CPC	Academia CPC	Industry CPC
John Appleseed	High *Industry* CPC	3.80	4.95	5.10
Paul Revere	Medial *Industry* and *Academia* CPC	3.25	4.30	4.30
Oliver Twist	Low CPC for all	3.40	3.90	3.90
Theo Roose	Medial *Industry* and *Healthcare* CPC	3.80	4.10	4.00
Tom Jefferson	High *Academia* CPC	3.85	5.10	4.44
Kennedy Johnson	Medial *Academia* and *Healthcare* CPC	3.95	4.15	3.90

the resumes were identical to ensure that the descriptions of the skills and experiences were the differentiating factors of the DRs to be evaluated. For instance, the grade point average for all six resumes was specified to be a 3.85 on a 4.0 scale and all resumes had bachelor's degrees in biomedical engineering. The lengths of time in which the resumes indicated participation in the experiences represented on the DRs were also kept unspecified as they have been found to impact reviews [18].

To verify the alignment of the DRs with the rubrics they were inspired by, the first and second authors independently scored the DRs and evaluated the relative differences in resume strength within and between resume sets. Though focus was on collecting information from academic and industry reviewers, the authors assigned healthcare, academia, and industry CPC scores to all seven DRs by giving each skill or experience listed on a DR a score from 1 to 6 based on the skill or experiences' corresponding tier on the corresponding rubric to understand alignment of the DRs to each pathway. Paired, two-tailed *t*-tests that compared the first and second authors' scores for the skills on each DR according to each of the three rubrics (academia, industry, and healthcare) indicated that there is no significant difference in the first and second authors' application of the rubrics to the DRs ($0.08 \leq p \leq 1$; $\alpha = 0.05$). The sum of the scores for all of the skills or experiences on the DR was then divided by the total number of skill or experience entries to obtain the DR's pathway CPC score. The averages of the first and second authors' academia, industry, and healthcare CPC scores (out of a possible 6) were taken for each DR (Table 3) to evaluate the alignment of the DRs between and within the resume sets and compare this to our intended resume alignment and ranking.

When evaluating the scores of the resumes according to the rubrics, we wanted to ensure that the resumes were appropriately scored for students with only undergraduate experience and obtained CPC scores that reflected their expected relative order within their sets. The resumes we collected from the undergraduate students for this study did not have many of the skills or experiences that would have scored 6-points on the rubrics. As such, the high-quality DR in each set obtained average CPC scores of around 5 on a scale from 1 to 6 (refer to Table 3). Despite this, we verified that for each of the two high-quality DRs, their highest average CPC score was in the career field that corresponded to their resume set. For instance, Tom Jefferson's average Academia CPC score was higher than both its average industry and healthcare CPC scores, demonstrating its specificity and strength as an academia DR according to the corresponding rubrics. Furthermore, these two DRs received higher average CPC scores than all the others when evaluated by their corresponding rubric. These results confirmed that we had created aligned resumes in each career path based on the rubrics.

The two, middle-quality DRs were designed to score lower than the high DRs for each career pathway set and receive similar scores to each other based on the rubrics. Based on the results presented in Table 3, we achieved this goal as the middle-quality resumes scored at least 0.65 points (out of a possible 6 points) lower than the high scoring resumes within each set. Furthermore, the average difference between the two middle-quality resumes in each set was around 0.2 points, indicating a close match between the middle-quality resumes in terms of rubric scores.

Finally, we designed a resume (Oliver Twist) that was intended to score lowest across all three career pathways. Oliver Twist was not the lowest scoring resume in the healthcare pathway according to the rubrics and our scoring, but since we collected data only from academia and industry reviewers, we did not make changes to the Oliver Twist resume to try to reduce its score further.

Survey Development

After verifying that the rubric scores ranked the DRs assigned to each set in the order we expected, we developed a Qualtrics survey to gather feedback from academia and industry reviewers. Based on survey participants' self-identified career pathway alignment, the survey assigned each reviewer to one of the two resume sets and asked them to evaluate four DRs (one high, two middle, and one low quality) for approximately 5–7 min without a specific job posting as a prompt. Resume sets were shared with participants using Google Drive Folders linked in the survey. Once participants had reviewed the resumes, they were asked to respond to three quantitative questions. First, reviewers were asked to rank the four resumes in order of the likelihood that an interview offer would be made. This question encouraged reviewers to evaluate each resume in relation to the others within the set. Afterward, reviewers were tasked with assigning each of the four DRs a rating from 1 to 5 (1 = poor and 5 = excellent). Ratings allowed reviewers to evaluate the overall quality of the DRs, without having to judge them against one another. Finally, reviewers were asked whether or not they would offer an interview for each fictional applicant based on their resume alone. These quantitative questions were meant to capture data related to those collected in other resume studies (e.g., field studies, incentivized resume reviews) [1, 6, 19, 20].

Participants were also asked qualitative questions, where they could provide the rationale behind their rankings, ratings, and interview offer choices and evaluate the features of each DR that guided their decisions. These qualitative, open-ended survey questions were as follows:

(1) What about the top-ranked resume made it stand out to you?

(2) Looking at the resumes you ranked number 1 and 2, what information on their resumes makes them a good applicant?
(3) Looking at the two resumes you ranked last, what made you place them in those positions? What may have disqualified them from being interviewed?
(4) For each of the four resumes, what were the biggest positive features (skills, experiences, etc.) that you noticed first?
(5) For each of the four resumes, what were some features (skills, experiences, etc.) that you would have liked to see?
(6) In general, do you have any further insights to share regarding key experiences, skills, etc. that would lead you to offering an applicant an interview?

These qualitative survey questions prompted reviewers to provide examples of positive and negative features of each DR and to reflect on how these features influenced their responses to the quantitative questions. No time limitations were imposed upon reviewers, though reviewers were advised that the entire survey would take approximately 30 min to complete.

Survey Distribution

We were not able to incentivize participation in this survey, so much of the efforts to gain feedback on the resumes created leveraged social networks of the researchers on the project. The limitations of this approach are discussed further in the limitations section of the paper. Initially, the authors utilized their social networks to reach employers and distribute the survey. The authors shared the survey through posts on LinkedIn accounts, relevant Slack workspaces they were part of [e.g., the Biomedical Engineering Education Community (BEEC) Slack], and through personal outreach emails to BME employers working in industry and academia asking them to share the survey broadly. In an effort to disseminate the survey more, the survey was later distributed to attendees of the 2022 American Society of Engineering Education (ASEE) Conference during a poster presentation session using QR codes that were printed on handouts. Five academia responses and nine responses from industry reviewers were obtained prior to the ASEE conference. One additional academia and three additional industry responses were obtained after the conference.

Data Analysis

After the survey responses were collected, the authors used a combination of quantitative and qualitative methods to analyze reviewers' perceptions of the DRs.

Quantitative Methods

The relative rank order of DRs (high, middle, low) was established within each resume set during the resume construction process and verified using the average CPC scores (Table 3). These results served as the expected ranking against which the obtained rankings were compared. Since the two middle-quality DRs in each resume set were created to be nearly identical, all of the middle-quality DRs were assigned a ranking value of 2.5 within their sets to place them equally high in rank order of 4 items. The high-quality DRs in the resume sets were given expected ranking values of 1 and the low-quality DRs were expected to rank fourth (4). Similar to the rating results, the obtained rankings for each DR were averaged to obtain a single representative value for the reviewers' rankings of that DR within its set. *T*-tests and the equivalent non-parametric Mann–Whitney *U*-tests were used to determine whether the differences between the expected and obtained ranking values of the DRs within each set were statistically significant or not. Lastly, the authors analyzed the trends in interview offerings within and between the resume sets. For each of the DRs, the number of reviewers working in their set's corresponding career field that answered 'yes' to extending interview offers was calculated. We then explored the data for trends among the individual reviewers' rankings, ratings, and the extension of interview offers to determine whether the differences in resumes' rankings or ratings translated to differences in interview offers.

The authors established the expected ratings for the DRs that were included in each set as their average CPC scores from resume development (Table 3). The expected rating of a DR within a given resume set was then compared to the average of the obtained ratings from reviewers working in the corresponding career field. For the DRs in multiple resume sets, separate ratings scores (out of 6) were calculated from each set of survey respondents. Because the rating scale was different in the survey (1 to 5) than the rubrics (1 to 6), the survey scores were adjusted (normalized to be a value from 0 to 1 and then multiplied by 6) to the rubric scale so comparisons could be more easily made. *T*-tests and the equivalent non-parametric Mann–Whitney *U*-tests comparing the obtained and expected average CPC scores were conducted to determine whether the expected ratings for the DRs in each set were significantly different from those obtained from reviewers.

Qualitative Methods

The authors conducted a thematic analysis of the responses to the survey's qualitative questions [21]. This process began with an initial readthrough of the data to look for trends in the features of the DRs that reviewers took note of in

their responses. These trends were used to define codes that represented the aspects of resume construction and resume content that reviewers identified as positive, negative, or missing from the DRs (e.g., clarity, leadership, laboratory experience). Since the qualitative survey questions probed reviewers for their thought process behind the rankings and ratings of resumes, the authors also created codes to represent how reviewers interpreted certain features of the DRs (e.g., creativity, versatility, depth of involvement). After these codes were established, the authors organized them into general categories that each encompassed several codes (e.g., resume construction, non-technical skills/experiences on resumes). In total, 5 general categories and 33 codes were created and are summarized in Table 4. The established codes and categories were then used to identify and study themes in the qualitative survey data. To ensure that the application and understanding of the codes were consistent between the two authors, discrepancies in interpretation were regularly discussed throughout the coding process. Once the coding was completed, we looked for trends in how frequently codes appeared or grouped together to analyze trends in the reviewers' perceptions of the skills and experiences on the DRs. These analyses yielded several themes regarding reviewers' perceptions of the skills and experiences represented on the DRs. In general, we aimed to use the codes to explore trends of valued and devalued features of resumes in each pathway and examine the alignment of these trends to those in the established rubrics that the DRs were based on, contributing recommendations for modification of the rubrics where appropriate.

Authors' Positionality

At the time that the study was initiated, the first author was an undergraduate student that was pursuing a Bachelor's degree in BME and had been conducting BME education research for 3 years. She was initially interested in this work to examine what the professional outcomes of a BME degree were. At the time of study initiation, the second author was finishing a PhD in BME with a focus on professional preparation and development of BME students in her research work. Together, the authors have investigated the professional preparation of BME students through multiple complementary studies and have dedicated substantial time to understanding the gaps in knowledge of what professional preparation looks like from the perspective of the multiple parties invested in BME education. This work was motivated by the limited understanding of what evidence employers use as indicators of the professional skills that are widely studied in the field.

Results

A total of 18 survey responses were collected, consisting of 12 from industry professionals and 6 from academia professionals (Fig. 2). Despite multiple efforts, we were unable to collect additional responses from academic or industry reviewers. Three themes were identified from the survey data regarding the perceptions of industry and academia reviewers on the skills represented on BME student resumes:

(1) *Rubric Alignment* on average, reviewers' perspectives aligned with the BME resume rubrics.

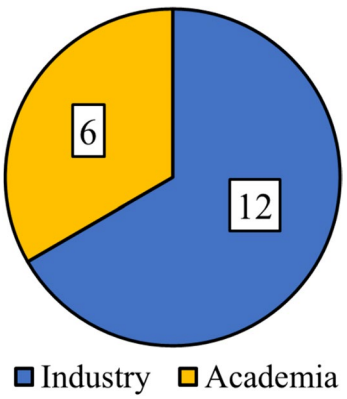

Fig. 2 Number of responses by reviewer type

Table 4 Codebook overview

Category	Codes
Resume Construction	Detail, quantitative representation of skills, clarity, skill list, activity time, action words, general
Non-technical skills/experiences on resumes	Leadership, depth of involvement, diversity of experiences, extracurricular involvement, creativity, teamwork, other soft skills
Technical skills/experiences on resumes	Engineering design, pathway specific skills/experiences, application-based experiences, service/impact, academics, MCAT, communication, internships/industry experience, research experience, clinical experience, laboratory experience
Implications	Versatility, collaborative, creativity, depth of involvement, alignment of experiences with job position, interest alignment
Other	Need for supplemental material for evaluation, no distinguishment between resumes

(2) *Content Interpretation* representation of resume content and experiences can have specific implications, but often resumes are not enough information for hiring.
(3) *Pathway Misalignment* academia and industry reviewers differ in the experiences and skills valued on BME resumes.

Theme 1: Rubric Alignment: On Average, Reviewers Align with the Resume Rubrics

In Theme 1, which addresses the first research question about the qualities, skills, and experiences reviewers are looking for in resumes, we explored the alignment of the reviewers' perspectives with the pre-established rubrics and with other reviewers. The obtained ranking, rating, and interview offer results from the academia and industry reviewers and expected values from the rubrics are shown below (Tables 5, 6, 7). Rankings from one industry and one academia reviewer were not collected and were excluded from ranking analyses (Table 5). In this theme we present comparisons between our results and the reviewers' ratings and rankings and discuss their decisions to offer interviews.

While the reviewers' ranking of the industry DRs was consistent with their expected order (Table 5), the ranking results for the academia DRs did not align with the order that was predicted. We expected the Oliver Twist DR to rank the lowest among the academia resumes based on CPC scores, but, on average, the academia reviewers placed Oliver Twist above Kennedy Johnson in the overall ranking. This result indicated that the academia reviewers perceived Oliver Twist to be a stronger candidate than we had anticipated based on the rubric scores. To explore the statistical significance of these observed differences, we performed *t*-tests and the equivalent non-parametric Mann–Whitney *U*-tests. Overall, the differences between the rubric-derived and reviewer rankings were found to be not statistically significant through both *t*-tests ($0.24 \leq p \leq 0.94$; $\alpha = 0.05$) and Mann–Whitney *U*-tests ($0.28 \leq p \leq 0.92$; $\alpha = 0.05$). Similarly, *t*-tests to explore the statistical significance of differences in reviewer rankings of the two, middle-quality DRs in each set were performed. The *t*-test ($p = 0.63$; $\alpha = 0.05$) and Mann–Whitney *U*-test ($p = 0.94$; $\alpha = 0.05$) comparing reviewers' rankings of the two, middle-quality DRs in the industry set indicated that the Theo Roose DR was not ranked significantly higher than the Paul Revere DR (and vice versa) by industry reviewers. Similar results were obtained from the *t*-test ($p = 0.47$; $\alpha = 0.05$) and Mann–Whitney *U*-test ($p = 0.51$; $\alpha = 0.05$) comparing the obtained rankings of the two middle-quality academia DRs.

Overall, the obtained average CPC scores of the Academia and Industry DRs aligned with the predicted rubric ratings (Table 6). *T*-tests ($0.10 \leq p \leq 0.94$, $\alpha = 0.05$) and Mann–Whitney *U*-tests ($0.12 \leq p \leq 0.92$, $\alpha = 0.05$) indicated that the differences between the rubric and employer ratings of the individual DRs were statistically insignificant.

We also wanted to explore if there were differences between reviewer ratings of the two, middle-quality DRs in each set. The *t*-test ($p = 0.40$; $\alpha = 0.05$) and Mann–Whitney *U*-test ($p = 0.59$; $\alpha = 0.05$) comparing reviewers' ratings of the two middle-quality DRs in the industry set indicated that there was no significant difference between the reviewers' ratings of the Theo Roose and Paul Revere DRs. Similar conclusions were drawn from the *t*-test ($p = 0.62$; $\alpha = 0.05$) and Mann–Whitney *U*-test ($p = 0.56$; $\alpha = 0.05$) comparing the obtained ratings of the two middle-quality academia DRs.

Overall, all of the evaluated resumes received interview offers from over half of their respective reviewers (Table 7). The Tom Jefferson and John Appleseed DRs were offered

Table 5 Expected vs. average obtained ranking values (industry $n = 11$, academia $n = 5$)

Expected	Academia obtained		Industry obtained	
1	Tom Jefferson	1.00	John Appleseed	1.55
2.5	Kennedy Johnson	3.20	Theo Roose	2.55
2.5	Paul Revere	2.80	Paul Revere	2.73
4	Oliver Twist	3.00	Oliver Twist	3.18

Table 7 Interview offerings (Industry $n = 12$, Academia $n = 6$)

Academia		Industry	
Tom Jefferson	6	John Appleseed	12
Kennedy Johnson	4	Theo Roose	10
Paul Revere	4	Paul Revere	9
Oliver Twist	5	Oliver Twist	7

Table 6 Expected vs. obtained average career pathway competency (CPC) rating values (Industry $n = 12$, Academia $n = 6$)

Academia			Industry		
Resume	Expected CPC	Obtained CPC	Resume	Expected CPC	Obtained CPC
Tom Jefferson	5.10	5.80	John Appleseed	5.10	4.80
Kennedy Johnson	4.15	4.00	Theo Roose	4.00	4.50
Paul Revere	4.30	4.40	Paul Revere	4.30	4.20
Oliver Twist	3.90	3.80	Oliver Twist	3.90	3.80

interviews by all of the academia ($n = 6$) and industry reviewers ($n = 12$), respectively. As was expected based on the rubrics, the Oliver Twist DR was given the fewest interview offers (7; 58%) of the industry DRs; however, it had the second-most offers from academia reviewers (5; 83%). The academia offer results were unexpected and indicate that the skills represented on the Oliver Twist DR were seen as potentially more desirable by academia reviewers than industry reviewers, further supporting the unexpected results we found in the rankings data.

An interesting pattern we saw was in the industry resumes rated and ranked in the middle of the set (i.e., Paul Revere and Theo Roose). Despite statistically insignificant differences between their ratings and rankings, Theo Roose was both rated and ranked slightly higher on average and offered one more interview than Paul Revere. The additional interview offer that was extended to Theo Roose indicates that the perceptions of these resumes differed enough to result in different interview outcomes, even in our small dataset. Overall, there seems to be some level of ambiguity in how resume reviewers interpret what is presented on the resumes that moves beyond what a quantitative rubric can capture. To explore that ambiguity, we looked at the qualitative feedback provided by our reviewers in Themes 2 (Content Interpretation) and 3 (Pathway Misalignment).

Theme 2: Content Interpretation: Representation of Resume Content and Experiences Can Have Specific Implications, But Often Resumes Are Not Enough Information for Hiring

Given that slight misalignments existed in our data between our expected and obtained results, we explored the impact of resume construction on reviewer perceptions qualitatively through our second theme. The results presented in Theme 2 also align with research question two on how qualities, skills, and experiences can be represented on resumes. Theme 2 explores ways particular elements of a resume can communicate specific things to the reviewer reading the resume. We saw feedback from reviewers that the level of detail provided in a resume could be interpreted to indicate the depth of involvement or the alignment of skills to a role they could be hiring for. As an example, one industry reviewer discussed how, "Details on their contribution, suggests they understand what is required for the position." Another industry reviewer said, "First, the language and the amount of information provided for each experience, felt like it provide(d) me with enough information to know what their roles were." which indicates the value of providing detailed information regarding an experience on a resume. This practice ensures that there is not a miscommunication about the scope or nature of a project based on the short title line that is common on resumes. Academia reviewers discussed similar perceptions saying things like, "demonstrated activities working with others, detailed information about project contributions." One example of how this showed up differently in the DRs we created can be found in the descriptions of activities in the Collegetown Medicine experience demonstrated in Table 8.

Additionally, reviewers stated that they interpreted depth of involvement through resume features like quantitative representations or clarity of descriptions. For example, one industry reviewer said,

> The skills are outlined in a generic form. Industry cares about quantifiable outcomes like Publications, presentations, awards, etc. that demonstrate clear acquisition of skills. [...] Preference is for clear examples of outcomes like building a home if you were part of Habitat for Humanity or collecting X tons in a food drive or spending 100 hrs reading for kids in library X/Y, etc. Again, action oriented descriptors go a long way.

Another industry reviewer noted, "make sure there's clear impact (% change in efficiency, $ impact, publication, etc... have some metrics). List publications/conference proceedings [and] demonstrate outcomes."

Many of the industry reviewers indicated that they would have liked to see skills lists on our DRs which indicates the importance that industry resume reviewers place on this resume feature. Examples of feedback calling for skills lists include:

Table 8 Example of increasing detail for a similar experience on designed resumes (DRs)

Experience: Collegetown Medicine	
Least detailed	Designed a report on system operations and data analysis results for Collegetown Medicine
	Presented models and data analysis results using multiple communication methods (e.g., written, verbal, and visual communication methods) at a university research symposium
	Communicated complex simulation models, optimization concepts, system operations, and data analysis results for different audiences via combination of written, spoken, and visual communication methods, including presenting at an annual multi-organization meeting
Most detailed	

- "I also like a quick summary of any special skills that may be unique or above the normal expectation. For instance if you're really good at excel macros that's something above the average excel usage expectations. If you have experience with Microsoft apps and linking things together etc. Skills in lab are always helpful in bullet points if you're applying for lab related positions."
- "Well defined Tools and skillsets...Couldn't gather candidates competency and skillsets…skills list with detailed skills/abilities"

In some instances, it seemed that the presence of qualifying skills may not have been sufficient to make a resume rise to the top of a reviewers' priorities. We observed differences in the reviewers' perceptions of the resumes based on factors like the potential (mis)alignment of an applicant's priorities with the job based on their involvement. As an example, two academia reviewers favored Oliver Twist over Kennedy Johnson and Paul Revere in the ratings and rankings. One noted that "[Johnson] could make a good MD/PhD student, but clearly he's planning on medicine… Revere is a designer and builder, so I would think great for industry" while Oliver Twist "has done some aspects of [research and has] some interest in teaching and collaboration." In this instance, it appeared that the academia reviewer was questioning Johnson's dedication to a PhD only path, and prioritized Twist's limited research and teaching experience over Revere's design experiences, even with similar skills discussed on the resumes. However, these reviewers' sentiments were not universal. Two other academia reviewers placed more emphasis on the applicants' depth of involvement with research in their evaluations of the resumes. Both ranked Oliver Twist at the bottom of the academia set because the resume had "fewer details that were qualitative/descriptive about his work/involvement" and needed "more information about just how involved in the research they were."

Beyond introducing some nuance into the ways that resumes can be interpreted beyond the skillsets present on the resume, this theme explores the limitations of a resume as a deciding factor for reviewers. A number of reviewers noted that while there were some noticeable enough differences to rank the resumes, they were all of high enough quality to invite for an interview. These reviewers also discussed how important the interview stage can be in deciding between candidates who are otherwise similar on paper. One good example is described by this academia reviewer: "I would have interviewed all four, but whether the last two ranked get offers would greatly depend on their interview. I would want more information about just how involved in the research they were (i.e., do these line items on their resumes accurately depict how familiar they are with the research process)." Other academia reviewers also discussed the need for additional materials in conjunction with a resume during the screening phase to assess applicants' intent to pursue research (e.g., research statements, recommendations, paper citations/links). While industry reviewers shared the sentiment that the resumes were not sufficient for hiring decisions, they tended to note the importance of personality and team fit (as assessed during interviews) as supplemental factors in their evaluation of applicants for a final job offer.

In summary, this theme leveraged qualitative, open responses to explore the nuances behind the observed differences in ratings, rankings, and offer decisions from Theme 1 (Rubric Alignment), indicating that while rubrics might be helpful in creating a high-quality resume in terms of the skills described, reviewers take additional factors (e.g., perceived depth of involvement and alignment of skills and experiences, qualifications that cannot be well represented on a resume) into consideration and these factors may ultimately impact their decisions to offer an interview and move a candidate to the next stage of the application process.

Theme 3: Pathway Misalignment: Academia and Industry Reviewers Differ in the Experiences and Skills Valued on BME Resumes

In addition to resume construction factors, the skills and experiences represented on the DRs impacted reviewers' perceptions of the candidates. In Theme 3, we examined the skills and experiences that academia and industry reviewers found desirable on the DRs to identify the differences in their perceptions of the skills. The percentages of academia and industry reviewers that noted certain skills as favorable or lacking features of the DRs in their open-ended responses are captured in Table 9 and were used to evaluate the relative desirability of the skills to academia and industry reviewers. These percentages were calculated by dividing the number of industry and academia reviewers that noted each skill as a favorable or lacking feature of the DRs in their open-ended responses by the total number of industry ($n = 12$) and academia ($n = 6$) reviewers and multiplying by 100. The "MCAT" code was excluded as its inclusion on the resumes was the only code we found that had been perceived negatively by some reviewers. This negative perception is described more below.

Technical Skills

We also examined the content of the open-ended survey responses under each of the technical and non-technical skill codes to understand the academia and industry reviewers' perceptions of resume skills. For instance, we heard mixed feedback from resume reviewers about what the presence of an MCAT score might indicate to reviewers; the way this skill was presented had the potential to communicate a (mis) alignment of skills. Generally, industry reviewers had strong

Table 9 Skill desirability (Industry $n = 12$, Academia $n = 6$)

Category	Code	AAES equivalent	Academia responses (%)	Industry responses (%)
Non-technical skills/experiences	Leadership	Teamwork (Tier 3)	83	50
	Depth of involvement	–	100	17
	Diversity of experience	–	67	42
	Extracurricular Involvement	–	50	17
	Creativity	Creative thinking (Tier 3)	0	8
	Teamwork	Teamwork (Tier 3)	50	42
	Other 'soft' skills	–	0	8
Technical skills/experiences	Engineering design	Foundations of engineering design (Tier 4)	33	58
	Pathways specific skills	Industry-specific functional areas (Tier 5)	17	25
	Application based	Working with tools and technology (Tier 3)	0	25
	Service/Impact	Client/stakeholder focus (Tier 3)	50	33
	Academics	–	0	25
	Communication	Communication (Tier 2)	100	25
	Internships/Industry experience	Industry-specific functional areas (Tier 5)	50	33
	Research experiences	–	100	33
	Clinical experiences	–	50	25
	Laboratory experiences	Science and technology (Tier 2)	0	42

negative reactions to MCAT scores on the DRs. One industry reviewer said, "Don't put an MCAT score on a resume for industry - we'll know that we are a back-up to med school." The interpretations of the meaning behind MCAT scores from academia reviewers were more conflicting. One stated, "MCAT score may indicate more interest in med school than grad school," while another seemed more open to the idea of a student who included an MCAT score saying, "I would interview Kennedy Johnson, who could make a good MD/PhD student, but clearly he's planning on medicine, and we'd have to find out if he wanted to continue research."

Though academia reviewers were more concerned about the (mis)alignment of the applicants' skills to their intended career field than their industry counterparts, the reactions to the MCAT score on resumes showed that many academia reviewers were also more forgiving in their evaluation of misaligned skills on resumes. We deduced that this is because academia reviewers often interpreted traditionally misaligned resume skills to be indicative of the applicants' research interests. For instance, one academia reviewer remarked that "If a student is interested in devices, it would be great if they had hardware experience. If they are interested in computation, it would be great if they participated in a hackathon or something similar. I generally look for experiences/skills on their resume that are synergistic with the type of research they want to conduct in grad school." This implies that the inclusion of skills that are traditionally misaligned with academia (including clinical and internship/industry experiences) can be perceived as a positive feature on an academia resume if connections were made to the applicant's desire to pursue research. The results from Table 9 also indicate that half of the academia reviewers perceived clinical and industry/internships experiences as desirable.

Interestingly, one academia reviewer expressed that these traditionally misaligned experiences could indicate a strong interest in academia: "I think an internship is usually a good experience to have to give them a sense for what industry is like. There's a big difference in pursuing an MS and a PhD, and having a clear idea of which of those things is necessary for the career path you are pursuing is essential." In other words, industry or healthcare-inclined experiences on academia resumes can be interpreted by academia reviewers as experiences that academia applicants used to rule out interest in the other career pathways.

Though misalignments between the applicant's experiences and their intended career field were tolerated by many academia reviewers, we observed that a lack of research was not. Though one academia reviewer noted the misalignment of both Kennedy Johnson and Paul Revere with academia, only Revere was declined an interview because he lacked "some evidence of research in addition to design." Another said that the skills on Revere's DR indicated a "lack of fit for PhD program admission … (lacking research)." Moreover, since all of the academia reviewers indicated that research experience as a desirable skill on the DRs (Table 9), we inferred that research

experience was a vital skill for BME students pursuing careers in academia to demonstrate on their resumes.

Similar inferences were made regarding the industry reviewers' perceptions of internships/industry experiences. Though only 33% of the industry reviewers reported internships and industry experience as desirable skills (Table 9), those reviewers expressed strong opinions regarding the inclusion of these skills on resumes. One reviewer explained that their lowest ranking resume had "no industry experience; we get enough resumes that I don't need to spend time interviewing someone that never held a job outside academia." Another said "in general we do not look at GPA and [ ] weigh any industry experience higher than academic," and viewed internships as conveying "hands-on capability for a first out of college hire as they will generally be more lab oriented, and… [skills] that are important for a regulated industry like medtech including working with quality engineers, understanding standards, protocol development, and design control aspects like design verification." Design experience was also perceived as a skill that communicated, "hands-on design and prototyping experience as opposed to analysis and modeling." The reviewer also said, "This is critical in an R&D setting in a med device company." Taken together, industry and design experiences are valuable for developing application-based skills and indicating an applicant's general alignment of skills with industry.

However, we also inferred that engineering design and industry-oriented experiences were not equally valued by all industry reviewers. In particular, one of the industry reviewers that chose to offer Theo Roose an interview and not Paul Revere mentioned that, "for my company we are pharma and very science/biobased. So the CAD and python skills aren't as applicable." This means that Roose's clinical and biology-oriented skills were more aligned with the skills desired in pharmaceutical companies than Revere's engineering design skills. Another industry reviewer noted "surgery/hospital exposure" as missing from Revere's resume and as a positive quality of Roose's. Though this reviewer did not elaborate on why they perceive this experience to be valuable, this supports the sentiment that clinical experience is sought after by some industry reviewers.

Several academia reviewers also indicated diversity in research experiences—both in terms of research settings (clinical, laboratory, etc.) and responsibilities (presenting, writing, etc.)—as desirable features on student resumes. One academia reviewer stated that they perceived "the breadth and depth of their research experience, including presenting at conferences and helping write manuscripts" as indicative of both the applicant's interest in pursuing a career in academia and their ability to succeed in academia programs, also noting:

> If they are interested in research, I would expect them to have some previous experience with as much of the research process as possible. Not that students who don't have a lot of research experience do not deserve admission into a graduate program. But research is not for everyone, and if an applicant has been through the process and enjoys it enough to want to pursue it further in grad school, I am more confident in how well they will be able to transition into and succeed in a grad program.

From this reviewer's insights, we inferred that academia reviewers evaluated an applicant's intent to pursue and ability to succeed in academic programs by assessing their familiarity with the research process. Value was generally placed on research experiences because they were perceived to have provided opportunities for applicants to gain this familiarity, but this finding implies that applicants with limited research opportunities or experience may be able to demonstrate research process familiarity through other experiences on their resumes (e.g., emphasizing research elements in project-based courses).

In addition to research skills, Table 9 shows that communication skills were valued by all of the academia reviewers. In particular, evidence of writing ability in a research context was a valuable skill to demonstrate on academia student resumes. One academia reviewer noted that their highest ranked applicant "also had more experience with dissemination (i.e., the writing process) than the other candidates." Another mentioned that "For going into grad school, it is useful to know what it is like to take a research project all the way to publication, and only one has done that in a significant way," indicating that publications could be used to assess an applicant's research skills. Verbal and visual communications in research settings were also noted as valuable experiences: "the breadth and depth of their research experience, including presenting at conferences and helping write manuscripts [made them stand out]." Besides research, other co-curricular activities involving writing were also perceived as desirable by academia reviewers. One said, "I was drawn by the fact that [their top-ranked applicant] had experience as a Writing Fellow." Another reviewer favored the applicant who had "communicated results via written, verbal, and visual including presenting to upper management" and said that they "would have liked to see more about communication skills developed at the company [as an intern]" from others, indicating that industry-oriented experiences can provide communication skills that are desirable to academia reviewers. Thus, academia-inclined skills (research, communication, leadership, etc.) garnered from non-academic experiences may be important for academia applicants to emphasize on their resumes.

Non-technical Skills

Industry and academia reviewers often deduced leadership skills through applicants' mentoring experiences and the positions held in their extracurricular and co-curricular organizations. However, one industry reviewer noted that assessing and comparing the quality of leadership positions can be difficult: "leadership by association with societies while common is hard to use as a differentiator."

Interestingly, industry reviewers frequently discussed leadership in conjunction with teamwork. One industry reviewer noted that their lowest ranking applicant "seem[ed] more like they were there and participated rather than having a strong impact or leading… [I want to see more] leadership roles, [I] see [that they] can be part of a team, but can they lead people?" This sentiment aligns with the results presented in Table 9—leadership was indicated as desirable by more academia and industry reviewers than teamwork was. Other industry reviewers mentioned the "initiative to lead ... [and] experience with superiors, not just peers"' as important skills for applicants to demonstrate on their resumes and noted that "lots of collaboration experience means they will be able to work in an environment where there are multiple departments or stakeholders involved." This suggests that leadership and teamwork can be indicators of an applicant's ability to work within the multi-level leadership structures that are common in industry and academia.

In addition to leadership skills, extracurricular activities were used by reviewers to evaluate the diversity in applicants' experiences on the resumes. For instance, one academia reviewer said that their top-ranked applicant was "incredibly well-rounded and exceptional [as a] result of research lab experience resulting in publications, ability to … assist in developing research direction … extracurricular service with active engagement as a leader as well as his involvement as a writing tutor." Both academia and industry reviewers also seemed to perceive applicants with a broad range in experiences, including extracurricular activities, as having initiative, adaptability, and diverse skill sets:

- "I prefer candidates that have a diversity of experience, either in research or extracurricular activities [because] it can be hard to do things beyond UG research, so those students need to make an extra effort to gain these experiences (in general)." (academia reviewer)
- "Wide variety of experiences shows they are versatile and can keep up with a fast paced environment in which business drivers change frequently." (industry reviewer)
- "[Top applicant] showed a wide range of skills from hands-on work, data analysis, collaboration with cross-functional team members, and communication skills including written and verbal." (industry reviewer)

In this theme, we utilized the qualitative, open-ended survey responses to understand differences in how academia and industry reviewers interpreted the skills and experiences represented on the DRs. Our findings show that reviewers perceived technical experiences that generally aligned with academia (research experiences, communication) or industry (internship/industry and design experiences) as indicative of an applicant's interest and capability and non-technical experiences as communicating their ability to thrive in the field.

Discussion

Overall, our quantitative results indicated that the reviewers' perceptions of the DRs aligned with the expectations established by McCarty and Furtney's [18] resume rubrics, though some preliminary patterns of deviations were noted. Specifically, the academia reviewers had perceived Oliver Twist to be a stronger candidate than predicted and the industry reviewers ranked and rated Theo Roose and Paul Revere similarly, but ultimately favored Roose over Revere in the interview offers. These deviations indicated that there was a level of ambiguity in reviewer perceptions of the DR that could not be understood through quantitative measures alone. To address this, we leveraged the qualitative survey responses to (1) identify the resume features (Theme 2: Content Interpretation) and applicant skills (Theme 3: Pathway Misalignment) that reviewers found desirable and (2) understand what these features communicated to reviewers. Our findings in Theme 2 (Content Interpretation) indicated that the way that skills are represented and communicated on resumes makes a difference in how they are perceived by reviewers. In particular:

- Industry reviewers valued clarity in skill description on applicant resumes. Quantitative outcomes, skill lists, and higher levels of detail can communicate applicant ability and depth of involvement clearly and effectively on resumes.
- Skill alignment with academia and depth of involvement were strong deciding factors for academia reviewers' evaluations of applicants.
- Without specific prompting, reviewers noted the importance of interviews and other supplemental materials (recommendations, paper citations/links, research statements, etc.) in providing support for resume materials and assessing other applicant qualities during the hiring process.

In the last theme (Pathway Misalignment), we found that there were differences in how academia and industry reviewers perceived applicants' technical skills and experiences on resumes. For instance, our results indicated that engineering

design and industry experiences/internships were valued by industry reviewers for their ability to show application-based skills and general alignment with industry. Some differences were also observed in the perception of skills by reviewers from different industry sectors that warrants further investigation. Additionally, industry reviewers were less forgiving of misaligned skills while academia reviewers saw misaligned skills as having potential to strengthen an application if the skill's connection to research interests and familiarity were made clear on the resume. Research familiarity and communication skills were found to be vital skills to demonstrate on academia resumes and many reviewers noted that these skills could be communicated more effectively by emphasizing the quantitative outcomes (i.e., number of publications, presentations, awards) of the experience and by using skill lists. Overall, our results indicated that academia and industry reviewers tend to value technical experiences that generally align with their field (academia: research experiences and communication; industry: internship/industry and design experiences) and perceive these skills to indicate an applicant's interest and capability.

While some differences were noted in their perceptions of technical skills, academia and industry reviewers shared similar perceptions of non-technical skills on applicant resumes. Notably, both interpreted teamwork and leadership skills on resumes as demonstrating an applicant's ability to succeed in academia and industry. Extracurricular activities were interpreted as showing diverse skill sets, initiative, and versatility.

From our findings in Themes 2 (Content Interpretation) and 3 (Pathway Misalignment), we inferred that the academia reviewers perceived Oliver Twist to be a stronger candidate than expected (Theme 1: Rubric Alignment) because of the research experiences represented on his resume. Though Twist's research experience was relatively shallow, academia reviewers generally viewed this as a more direct indication of an interest and ability to succeed in academia than Johnson and Revere's design and healthcare experiences. This means that research familiarity, no matter how shallow, is important to demonstrate on an academia-focused resume because it communicates a clear alignment between the applicant's experiences and a career in academia.

Connecting Findings to Current BME Resume Guidance

In many ways, our study confirmed the value of McCarty and Furtney's [18] rubrics as a starting point for prospective employees as they craft their resumes or plan for opportunities to engage in preparation for a job search later on. And while our results obtained from a small sample of reviewers quantitatively aligned with what could be expected in the ratings and ranking of our DRs, differences in how many 'hypothetical interviews' our middle two resumes were offered indicated that a solely quantitative-skills-driven approach to resume guidance and construction may not be sufficient in crafting a compelling resume in a competitive job market. Furthermore, our sample was smaller than we had aimed for at the start of the project, likely partially due to the fact that we were unable to compensate reviewers for the time it took to take the survey. Given the variety of views we saw in qualitative responses, we wonder if we would have seen more significant differences had we been able to collect more data for the study.

The qualitative responses, however, were very valuable in informing our ability to make recommendations for how to improve resume construction and guidance. In many of the open-ended responses from reviewers, the way in which skills were articulated was just as, or more impactful, than just the presence of the skill on the resume. This finding demonstrated to us that a rubric targeted toward evaluating resumes on the basis of the presence of skills may not be a sufficient tool for crafting a compelling resume in a competitive hiring environment. These responses provide a context for advisors and prospective employees alike to consider ways they can better articulate their depth of involvement through detailed descriptions of their roles in a project alongside quantified metrics of their individual impact. The ability to concisely communicate skill development alongside depth of involvement, individual impact, and alignment with the posting for which a resume was being reviewed were the key characteristics of the highest quality resumes that our reviewers discussed. As such, we recommend that those who wish to use McCarty and Furtney's [18] rubrics as a starting point for drafting their resumes also consider reflecting on the overall writing in their resume as well. Some questions resume writers might wish to reflect on based on responses from our participants include the following:

- What was my individual contribution to this (project, position, organization)? How can my individual impact be quantitatively portrayed?
- What skills did I develop as a result of participating in this (project, position, organization)?
- What skills or experiences is the job I am applying to looking for? How do the experiences I have align with those skills or experiences?
- How can my resume help me tell a story of my career exploration so far, even if not all of my experiences align with the job I am applying for?

Limitations

While this study provides insights into how resumes are reviewed by BME employers in academic and industry professions, it is not without limitations. The first limitation comes from the limited number of respondents we were able to solicit for our survey, which not only limited the breadth of perspectives we were able to gather, but also limited our ability to perform meaningful statistics that could provide additional insights on the overall strength of current quantitative approaches to BME resume assessment (i.e., McCarty and Furtney's [18] rubrics). Given our reliance on social networks to distribute the survey initially, there are also potential limitations in the diversity of perspectives we were able to capture. We strived to mitigate the bias this approach might introduce by distributing the survey at a relevant national conference (i.e., ASEE) and in BME education focused collaboration platforms (e.g., the BEEC Slack). Respondents were also anonymous and did not provide demographic details in the survey, which allowed our respondents to share feedback without pressure to respond in specific ways or the potential for their responses to be tied back to them. However, it limited our ability to understand the types of roles our reviewers held in their professional positions. Similar future work may benefit from collecting some basic respondent role information to give context to the responses while protecting confidentiality and sharing the research opportunity with more organizational leaders as possible.

The open-ended nature of the qualitative survey questions was purposefully designed to elucidate the resume features that reviewers found to be most desirable in BME applicants, but this method is not without limitations. Notably, the reviewers may not have articulated skills or experiences that they may have considered to be inherent qualities of a qualified applicant in their responses. This likely contributes to the findings from Table 9 wherein 0% of academia responders indicated creativity, other soft skills, academics, laboratory, and application-based experiences to be desirable skills in applicant resumes. Although close-ended survey questions that list various pre-selected technical and non-technical skills for reviewers to indicate their desirability was a possible alternative to address this limitation, this method would not have allowed for proper exploration of reviewers' perceptions of desirable skills, as the included skills listed would have likely reflected our assumptions of desirable skills to reviewers.

In our study, we also compared the ratings of our DRs to rubric-generated CPC scores which pay attention only to skill strength. Our study leverages the idea that elements of how a resume is constructed can also play a role in the perspectives of reviewers. Indeed, we saw non-statistically significant differences in ratings between otherwise similarly designed resumes, which was supported by noted differences in our qualitative data. Our qualitative findings suggest that there are other important elements of resume design (e.g., the phrasing of an experience to demonstrate individual, quantifiable outcomes). A final limitation lies in the student population from which we drew example experiences, wherein we were pulling realistic experiences from students at a highly rated, R1 BME program that likely has the ability to connect students to far more hands-on experiences than other programs with non-research focused missions, fewer resources, or connections. Future work could explore the experiences of students in multiple BME programs with varying missions and student populations to gain a broader range of experience levels to design new resumes. Addressing this limitation in future work could contribute to a better understanding of an experience 'standard' needed in order to be considered for interviews and help us gain a deeper understanding of the utility of rubrics focused on skills for assessing resume design.

Future Directions

In addition, we hope that our study can inform future works that will help guide BME students' resume construction and professional development. In particular, since the applicants behind our designed resumes were implied to be white, cisgender male students attending a large research institution, future studies are needed to examine the impact that various demographic (e.g., race, ethnicity, gender, sexuality, ableness, political leaning) and academic factors (e.g., institutional prestige, length of involvement), as represented on resumes, can have on employers' perceptions of applicants. For instance, further investigations into the effect of experiences such as LGBTQIA+ organizations, Latinx/BSU/AAPI clubs, and involvement with Planned Parenthood, American Civil Liberties Union, or other organizations with political affiliations on resume perception can help create more holistic and realistic resume evaluation methods. Other factors, such as length of experiences and skill alignment with other BME fields, that were not evaluated in this study also warrant further investigation. Particularly, due to the wide range of specialties within the BME industry sector, additional research is needed to understand the perceptions of resume skills by BME employers from different industry specialties. Further insights into the development of pathway-oriented BME resumes can be made from comparisons of employer perceptions of BME and other engineering resumes (e.g., chemical engineering) within different sectors of industry (e.g., pharmaceuticals).

Furthermore, the recent rise in ChatGPT and Artificial Intelligence (AI) technology also shows potential for the development of automated resume review applications in the near future [22–25]. Based on our initial work, future graduates may apply McCarty and Furtney's [18] rubrics as a starting framework for such resume review applications, but our combined work has only served to move the boundaries of our understanding of what employers deem sufficient evidence of skills and abilities of applicants on resumes slightly. The emergence of AI tools for resume review makes understanding what sufficient evidence of skills and abilities looks like for employers all the more critical since employers are training the models that may eventually make a majority of initial hiring process decisions. If employers are not critically evaluating how they make the decisions themselves, biases in the review process are possible and likely. Given recent studies also indicate that Natural Language Processing tools may be able to detect gender or other non-explicit elements of a resume [26], continued studies that explore what employers implicitly and explicitly value on resumes, and how those values do or do not translate to be represented in the screening practices of companies are needed.

Lastly, since resumes often serve as an initial step in a longer application process, the importance of and factors affecting other steps in the hiring process (i.e., interviews) of BME applicants should also be studied to better prepare students for entrance into the job market. Because the first impressions made from resume reviews have been found to inform the way that recruiters interview candidates [4], further studies on the impact of resume qualities and skills on the interviewing approach that reviewers take may also help inform resume development.

Citation Diversity Statement

Recent work has demonstrated a bias in citation practices that has resulted in papers from women and other minority scholars to be undercited relative to the number of papers in their respective fields [27]. As authors, we recognize this bias and have worked to ensure we reference appropriate papers with fair gender and racial author inclusion.

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Data Availability Designed resumes are included as a publicly available supplement to this manuscript. Survey data may be made available upon request to the corresponding author.

Declarations

Conflict of interest The authors have no conflict of interest to declare.

Ethical Approval This work was reviewed by the University of Michigan Institutional Review Board (IRB) and determined to be no more than minimal risk and exempt from ongoing IRB oversight (HUM00189727).

Informed Consent Participants were prompted for consent at the beginning of the survey used for data collection. Their completion of the survey was indication of consent.

Consent for Publication Participants were prompted for consent at the beginning of the survey used for data collection. Their completion of the survey was indication of consent.

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