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Influences and inhibitors in STEM undergraduate social responsibility development

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Abstract

Background Numerous strategies have been applied to combat flat or declining social responsibility (SR) attitudes of undergraduate students in STEM fields. This paper presents the results of a five-year, mixed methods longitudinal study tracking a cohort of undergraduate students at the Georgia Institute of Technology. Drawing on the Professional Social Responsibility Development Model and the Generalized Professional Responsibility Assessment (GPRA), we analyze results from surveys ($n=124$ students) and interviews ($n=19$ students), each conducted twice at different time points during students' undergraduate education. Our focus is on the influence of different kinds of SR-related activities and experiences on student SR development over time, measured both quantitatively and qualitatively along several dimensions. Based on regression analyses controlling for pre-college attitudes, subgroup and path analyses, and triangulation with qualitative interview data, we identify key influences and inhibitors shaping SR development among STEM undergraduates.

Results Our results reinforce prior findings that student social awareness and professional development remain largely flat over time, and we observe a statistically significant decline in professional connectedness by graduation. We additionally observe a growing emphasis on salary as compared to helping others as a motivating factor in career decisions. Students report rare and unpersuasive efforts as part of in-major and STEM education to build SR, and other formal educational efforts like out-of-major SR activities or activities associated with institutional events have a modest impact as well. In contrast, the most common and positive influences occur *outside* of formal education. Peer interactions and personal exploration appear to be the most positive forces affecting SR development. Overall, while some students report an increase in basic social awareness, they also tend to report decreases in self-efficacy and few changes to their career orientations related to SR.

Conclusions Despite measurement challenges that occur outside of simpler pre–post-analyses or limited-term interventions, we encourage continued focus on holistic and longitudinal analyses. These may be needed to account for the complex interrelationships between different SR experiences and their impacts on personal and professional SR development. Overall, greater efforts are needed to measure, understand, and improve SR development for undergraduate students. We suggest that it may be important to both enhance the quality of disciplinary SR education in STEM and foster benefits of strategies like peer-based learning.

Keywords Social responsibility, Undergraduate education, Professional social responsibility, Ethics education, Surveys, Interviews, Mixed methods

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Introduction

Science and engineering professionals have tremendous influence in shaping society. In turn, professional associations, scholars, and employers consider how to ensure that this influence is used responsibly toward securing societal benefits as well as minimizing harms (Cohen & Grace, 1994). Yet, while the need to define and uphold professional social responsibility has crystallized in recent decades (Layton, 1986; Wyndham et al., 2015), continued lapses and failures to safeguard the well-being of the public (e.g., Herkert et al., 2020; Mansouri, 2016) caution that much work remains to be done (Kreth et al., 2024). There is debate surrounding, for example, the extent to which engineers should focus on macro-ethical dimensions of their careers as compared to more micro-ethical issues at one's workplace (Davis, 2006; Warford, 2016). Indeed, some STEM professionals maintain a minimalist conception of their responsibilities (Pritchard, 1998) focused on avoiding directly caused harms rather than promoting social good more broadly. In addition, despite the recognition that social responsibility is in principle important (Wyndham et al., 2015), Trim claims that engineers may remain motivated by financial and career considerations in practice (Trim, 2021), and recent quantitative research also finds relatively lower levels of SR among computer science undergraduates compared to students overall (Kreth et al., 2022).

A sometimes-overlooked component of social responsibility is that the roots of such attitudes emerge before STEM professionals begin their career. Because of this, scholars in engineering, computing, and other STEM disciplines have called for greater attention to educators and higher educational institutions, which play a special role in fostering—or failing to foster—social responsibility development in students (Hughes et al., 2020; Martin et al., 2021; Watts et al., 2017). Educational institutions at the postsecondary level face numerous barriers in this task. Culturally, they must grapple with a technical and meritocratic orientation in STEM that may de-emphasize or ignore broader social perspectives (Cech, 2010; Cech & Sherick, 2015). Pedagogically, educators may not be interested in or prepared to reform their practices to integrate ethics into the curriculum (Barkhuff et al., 2025; Bielefeldt et al., 2018; Fiesler et al., 2020; Katz & Knight, 2017). Finally, at the student level, educators inherit the challenge that students typically pick their professional direction due to intellectual interest and fit with one's skills, rather than because of social responsibility concerns (Schiff et al., 2021). It is not surprising that engineering students, for instance, hold varying conceptions about their responsibilities (Canney, 2013; Lin & Loui, 2017; Rulifson & Bielefeldt, 2019), and that student social responsibility attitudes appear to remain flat or even decline over the course of undergraduate education (Bielefeldt & Canney, 2016; Cech, 2013; Lathem et al., 2011; Schiff et al., 2024).

This paper reports the results of a five-year mixed methods study funded by the NSF aimed at understanding whether—and why or why not—student professional social responsibility attitudes develop within a cohort of undergraduate students at the Georgia Institute of Technology (Georgia Tech). Quantitatively, we administered the Generalized Professional Responsibility Assessment (GPRA) to the students at the beginning and end of their academic careers. Qualitatively, we interviewed a subset of these students at two time points as well to provide additional insights into what factors influenced or inhibited their social responsibly development. In tandem, our results reiterate concerns about the lack of attention to social responsibility development in STEM classrooms, but also urge newfound attention to factors, such as the role of peer and family influence, current events, and self-guided personal exploration in student SR development.

Background and conceptual framework

Ethics education and social responsibility development are closely intertwined (Kreth et al., 2024). Both address the cultivation of student knowledge, attitudes, and skill sets, such as ethical sensitivity and reasoning, as well as one's underlying sense of obligation (Martin et al., 2021; Osbeck et al., 2018). Professional social responsibility development can be understood as a subset or close sibling of ethics education focused on developing an ethical orientation with respect to one's workplace, discipline, career, and professional practice and impacts (Abbott, 1983; Banks, 2009), with linkages to concepts such as service learning, community engagement, corporate social responsibility, and sustainability education (Christensen et al., 2007; Forero & Gualdrón, 2024; Saari et al., 2024). While historically, professional ethics education has been especially dominated by micro-ethical concerns (Herkert, 2001), such as legal compliance and honesty in one's workplace, there has been a concerted if incomplete (Polmear et al., 2019) effort to incorporate macro-ethical considerations covering the broader impacts of one's profession on society (Herkert, 2005). Indeed, engineering ethics education has traditionally centered on case studies highlighting professional misconduct, safety risks, and the role of the individual engineer (Bucciarelli, 2008; Kline, 2010), and the majority of engineering students in the United States had no ethics education requirement throughout the twentieth century (Herkert, 2000). However, ABET's accreditation requirements contributed to a shift in this regard, largely with its "Engineering Criteria 2000" published in 1998 (Lattuca et al., 2006).

In response, scholars and professional associations have called for required ethics education, increased attention to macro-ethical or social dimensions of STEM, and an integrated ethics approach that cuts across the curriculum (Barakat, 2011; Knight et al., 2016; Mitcham & Englehardt, 2019). While case studies still play a prominent role, educators also employ role playing, discussion and reflection, codes of ethics, and even real-world exposure as pedagogical devices (Bielefeldt & Canney, 2014; Brummel et al., 2010; Hess & Fore, 2018). For example, service learning and community engagement are thought helpful in developing student awareness and empathy regarding societal challenges (Bernacki & Jaeger, 2008; Bringle & Hatcher, 2009; Butin, 2010; Vance-Chalcraft et al., 2024).

And though all of the above methods show some evidence of effectiveness, particularly in the short term, persistent challenges remain for both research and implementation (Martin et al., 2021; National Academy of Engineering, 2016). Many studies involve small samples, esoteric institutional or cultural contexts, and research designs with limited validity. Moreover, research typically emphasizes a single mode of intervention, with a large focus on curricular interventions, framing out many other inputs that influence student experiences (Weidman, 1989). For instance, students participate in numerous activities and experiences, have different backgrounds and psycho-/socio-demographic characteristics, evolve over time, are shaped by particular cultures, people, coursework, and so on. Critically, these factors also interrelate in complex ways. Neglecting this complex reality spells problems for improving our understanding of student social responsibility development, for example, if we focus on short-term single intervention studies alone.

Our study utilizes several strategies to contribute to building knowledge in this context and is based on our prior work in this realm (Kreth et al., 2022, 2024; Schiff et al., 2021, 2024). First, we followed a cohort of undergraduate students at Georgia Tech, a predominantly STEM-focused institution, throughout their undergraduate education. Second, our mixed methods approach involved both the administration of the GPRA (Borenstein et al., 2019), a survey instrument adapted from the Engineering Professional Responsibility Assessment (Canney & Bielefeldt, 2016), and semi-structured student interviews, providing breadth and depth to our longitudinal analysis. The survey instrument and interview approach draw conceptually from the Professional Social Responsibility Development Model (PSRDM), which treats personal development and professional development as precursors to a combined sense of professional social responsibility (Canney & Bielefeldt, 2015). Finally, we took a holistic approach to understanding the influences and inhibitors in student social responsibility development, allowing us to understand a wide variety of factors that may play a positive or a negative role, such as courses, peers, community engagement, internships, student characteristics, personal exploration, and campus organizations. In conjunction, our five-year study sought to answer the following key questions:

- *How do student personal and professional social responsibility attitudes change during the course of undergraduate education?*
- *Which factors serve as influences and inhibitors in student social responsibility development?*
- *What role do student demographic characteristics, such as race and gender play, if any, in social responsibility development?*

In the following sections, we describe our mixed methods approach and research design before presenting our results and discussion.

Methodology

Study site and context

This study took place at Georgia Tech, a large, predominantly engineering-focused institution in the United States. Further, this institution was chosen because, beyond serving as a viable site for understanding STEM education generally, the university was also beginning at that time an initiative focused on service learning and sustainability. Aspects of the institution's culture, mission, motto, and coursework—inside and outside of STEM—implied there would be ample material for understanding student development over time. The study authors were also members of the institution, with access to student interviewees, survey takers, and administrative data. As observed in the paper's limitations sections, generalizing to other types of institutions and regions with different disciplinary mixes, cultures, and student characteristics should be done cautiously, and this study should be seen as only part of a broader body of necessary research.

Mixed methods design

To answer the questions above, we drew on both quantitative and qualitative methods throughout the duration of our cohort's undergraduate education. Specifically, quantitative and qualitative aspects were given equal weight, with integration at the points of conceptualization, instrument design, analysis, and inference (Schoonenboom & Johnson, 2017). Each arm of the study thus informed changes to our research instruments, conceptualization, and research questions in subsequent

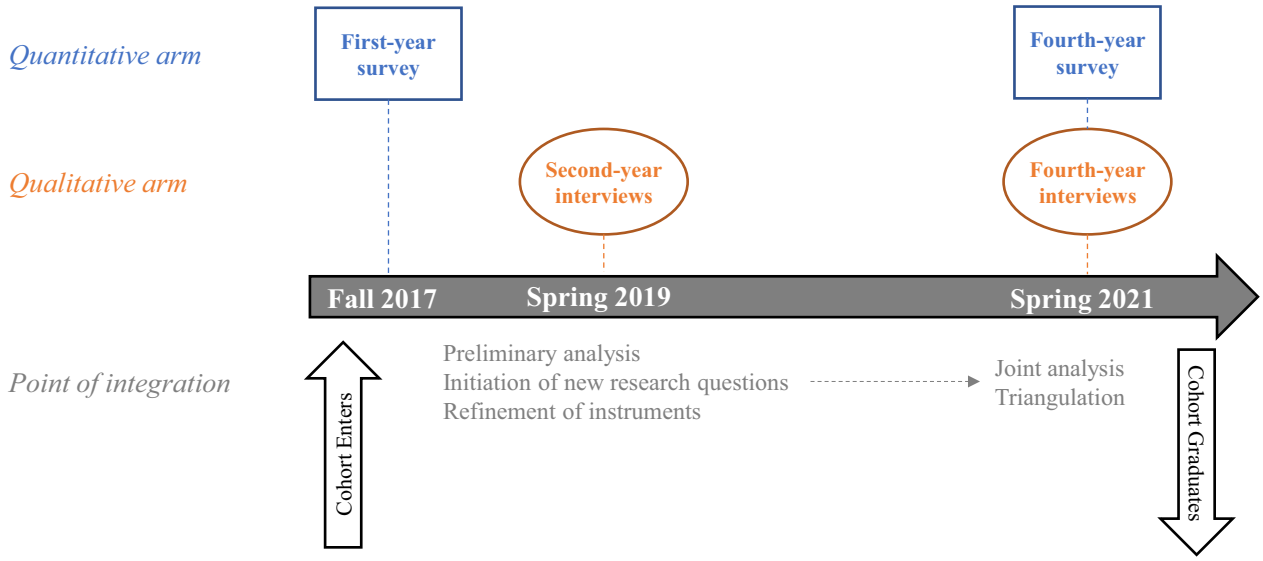

Fig. 1 Integrated mixed methods design; note that we sought to collect data from the entire cohort through the GPRA survey instrument but only sought to interview a subset of the cohort

stages, with purposes including triangulation, complementarity, development, and initiation (Greene et al., 1989). Students were surveyed at the beginning of their first year of college, (a subset) interviewed in the spring of their second year, and then both interviewed and surveyed in the spring of their fourth year. This QUAN → QUAL → (QUAN + QUAL) design is thus a three-stage equal-status integrated design, depicted in Fig. 1.

Quantitative approach

The GPRA quantitative instrument (Borenstein et al., 2019) was adapted from the Engineering Professional Responsibility Assessment (Canney & Bielefeldt, 2016) so that questions pertain to a broader set of students than engineers alone, which is the focus of the original instrument. We contacted the entering 2017 cohort through email a month before their first undergraduate semester with several reminders. 845 students of the total 2995 invited completed the 2017 survey. In 2021, we sent an updated version of the survey to the same cohort. Our primary sample is the 124 students who completed both the 2017 and 2021 surveys, including passing an attention check question and answering at least 90% of the core survey questions.[1]

The core of the GPRA is a set of 45 Likert-style questions[2] that measure a student's social responsibility across three realms and eight associated constructs according to the Professional Social Responsibility Development Model (PSRDM): *Personal Social Awareness* (constructs: Awareness, Ability, and Connectedness); *Professional Development* (constructs: Base Skills, Professional Ability, and Analysis); and *Professional Connectedness* (constructs: Professional Connectedness and Costs/Benefits). We describe the constructs and the corresponding realms in Appendix Table G1 (all appendices are available in a supplementary material file). In addition to the core survey instrument, validated in its original form[3] by Canney and Bielefeldt (2016), the broader survey also includes questions about student career values, frequency of participation in different community engagement and social responsibility activities, self-reported changes in sense of social awareness, efficacy, and moral obligation, and student demographics.[4] For the first version of the GPRA,

[1] Because differential attrition between the two surveys could introduce bias, we perform a logistic regression analysis to determine if student demographics and pre-college (i.e., 2017) social responsibility scores predict dropout. Women were slightly more likely to take the second survey, but overall a Cox-Snell R^2 test suggests non-random attrition is not a major concern (Goodman & Blum, 1996).

[2] After performing an exploratory factor analysis, we remove three questions from the initial set of 45 to improve construct-level reliability. We describe the factor analysis testing in Schiff et al. (2024).

[3] While the core PSRDM instrument was preserved across surveys, we modified some questions and incorporated others into the final survey in line with our evolving research questions. For example, we updated the list of community engagement activities to include specific student clubs at the university where the study takes place, and we incorporated new questions about social responsibility influences identified in the prior qualitative round.

[4] The full survey instrument, including the GPRA, is publicly available at https://osf.io/b4ysf/.

Table 1 Descriptive summary of key variables for quantitative sample ($n = 124$ respondents)

Variable	Mean (Std. Dev.)	Range	Variable	Mean (Std. Dev.)	Range
Dependent variables			Control variables		
Personal Social Awareness 2021	6.10 (0.62)	[3.72–7.00]	Gender		
Professional Development 2021	6.40 (0.55)	[4.28–7.00]	*Male*	0.38 (0.49)	[0,1]
Professional Connectedness 2021	5.43 (0.67)	[3.35–6.70]	*Female*	0.62 (0.49)	[0,1]
PSRDM 2021	5.98 (0.53)	[4.30–6.87]			
			Race/Ethnicity		
			White	0.64 (0.48)	[0,1]
Independent variables			*Non-White*	0.36 (0.48)	[0,1]
Overall College CE	45.81 (58.15)	[0–329]			
Overall SR Activities	100.41 (78.08)	[0–350]	College		
Professional SR Activities	37.66 (43.72)	[0–200]	*Engineering*	0.59 (0.49)	[0,1]
Personal SR Activities	62.75 (48.54)	[0–150]	*Non-Engineer*	0.41 (0.49)	[0,1]
SR Within Major	8.01 (14.92)	[0–50]			
SR Outside Major	8.42 (13.91)	[0–50]	Country of Origin		
SR Institution Event	12.53 (16.66)	[0–50]	*USA*	0.96 (0.20)	[0,1]
SR Internship	8.70 (15.93)	[0–50]	*International*	0.04 (0.20)	[0,1]
SR Discussion w/Friends	21.40 (19.11)	[0–50]			
SR Discussion w/Family	14.36 (15.65)	[0–50]	First Generation		
SR Personal Exploration	26.99 (20.74)	[0–50]	*Yes*	0.02 (0.15)	[0,1]
			No	0.98 (0.15)	[0,1]
Control variables					
Personal Social Awareness 2017	6.14 (.61)	[4.30–7.00]	Religious		
Professional Development 2017	6.39 (.54)	[3.00–7.00]	*Yes*	0.42 (.50)	[0,1]
Professional Connectedness 2017	5.65 (.75)	[3.17–7.00]	*No*	0.58 (0.50)	[0,1]
PSRDM 2017	6.06 (.52)	[4.59–7.00]			

(1) PSRDM refers to Professional Social Responsibility Development Model. (2) For the Community Engagement and Social Responsibility (SR) activity measures, we apply a simple scaling approach in alignment with the strategy used by Bielefeldt and Canney (2016), such that "have not participated" is multiplied by 0, "only a few times during college" by 1, "once or twice per year" by 2, "more than twice a year but not routinely" by 5, "monthly" by 20, and "weekly" by 50. We calculate the composite score for Overall SR Activities by summing the individual activity subscores. (3) Similarly, we calculate composite scores for Professional SR Activities and Personal SR Activities by summing individual activities attributed to one or the other categories: professional (within major, outside major, event, internship), and personal (friends, family, personal exploration)

many of the questions were tied to the students' pre-college experiences. However, in the endpoint version of the survey, at least some of the questions were revised to be more tailored to the specific collegiate activities at the home institution.

Our key outcomes are the PSRDM scores reflecting social responsibility attitudes over time. We average across the eight constructs to calculate three domain-level scores for Personal Social Awareness, Professional Development, and Professional Connectedness, and take a master average-of-averages to calculate an overall professional social responsibility score. Our primary independent variables are questions asking about the frequency of engagement with various "social responsibility activities or experiences," including through exposure to social responsibility issues inside and outside of one's major, conversations about these issues with peers and family, personal exploration (e.g., through reading news articles), internships or work, and events with student groups.[5] As described in Table 1, we pool these activities into "Personal" or "Professional" SR Activities scores, which jointly constitute an Overall SR Activities scores.

Finally, we draw on a set of demographics using survey responses and external, pre-defined administrative data, including gender, race/ethnicity, religiosity, academic major, first-generation status, and international student status. Based on these and other questions, we present descriptive patterns as well as results from regression analyses, aimed at demonstrating the frequency and impact of different social responsibility activities, and the

[5] We defined SR as "the obligation to become aware of and/or address issues that affect the public's well-being. Social responsibility can involve a person's or group's attempt to benefit the public." For a more detailed discussion about the relationship between SR, ethical or moral development, sustainability, community engagement, and other related concepts, please see Kreth et al. (2024). For a broader discussion of micro- and macro-ethical dimensions of SR, please see Schiff et al. (2021).

trajectory of student social responsibility development over time.

Qualitative approach

Our qualitative approach involved developing and administering a semi-structured interview protocol to a subset of the student cohort (Kallio et al., 2016). We recruited and interviewed 22 students in the spring of their second year of studies, and then re-interviewed 19 of these students in the spring of their fourth year.[6] These 19 students constitute the qualitative sample for this paper. The interviews were approximately 45–60 min in duration and students were typically asked around 15 questions. The interviews covered topics including student perceptions of their major and future profession, professional goals and values, social responsibility influences prior to college and during college, perceptions of the environment within their major and institution broadly, the impact of student characteristics on their social responsibility development, and their self-reported sense of change during college. Compared to the first interview, which emphasized pre-college and early collegiate influences in a more exploratory fashion, the second interview was more highly structured and addressed social responsibility influences and inhibitors throughout the college experience.

In the first stage, the research team created and refined a codebook based on the interview design and conceptual framework (Richards & Hemphill, 2018). The two researchers who performed the first-stage interviews used the Dedoose software package (SocioCultural Research Consultants, 2019) and engaged in asynchronous and synchronous coding and reliability testing with interview transcripts before finalizing the list of 41 codes. The research team then developed 21 five-to-seven page student memos summarizing the key findings (one interview was omitted due to poor audio quality). In the second stage, the researchers used the second-stage transcripts and the first-stage memos to produce a final set of 19 structured six-to-eight page memos aimed at capturing each student's overall experience (Birks et al., 2008). The research team reviewed all of these memos during our process of synthesizing findings and triangulating with quantitative results. For more details about the sampling approach, recruitment process, codebook development, interview protocol design, inter-rater reliability testing, and analysis strategy, see Schiff et al. (2021).

Table 2 presents basic sample characteristics for both quantitative and qualitative samples. Note that, while all students at the institution engage with engineering culture in a variety of ways, we deliberately included students outside of engineering for comparative purposes. Overall, our quantitative sample is 38% male and 64% White, with 59% of students in engineering majors. In comparison, our qualitative sample has a higher proportion of male (53%), non-White (58%), and engineering (74%) students.

Table 2 Student participants: comparison across quantitative and qualitative arms

Variable	Quantitative Sample ($n = 124$)	Qualitative Sample ($n = 19$)
Gender		
Male	38%	53%
Female	62%	47%
Race/ethnicity		
White	64%	42%
Non-White	36%	58%
College		
Engineering	59%	74%
Non-Engineering	41%	26%
Country of Origin		
USA	96%	74%
International	4%	26%
First generation		
Yes	2%	0%
No	98%	100%
Religious		
Yes	42%	47%
No	58%	53%

Results

Student changes in social responsibility and professional goals over time

A central question for our five-year study is whether students develop a stronger sense of social responsibility over time. While our qualitative evidence indicates some areas of improvement, namely in terms of increased social awareness, our quantitative and qualitative evidence overall points to stagnation, if not decline. This aligns with findings by Howland et al. (2022) and Cech (2010).

Figure 2 presents the overall changes between pre-college SR attitudes and SR attitudes near graduation across the three main realms of the GPRA. We find no statistically significant changes for both Personal Social Awareness (PSA) and Professional Development (PD), and even find a decline in Professional Connectedness (PROC) (decline of 0.22 points, $z\,(123) = -3.53$, $p < 0.001$

[6] Two students had graduated early and declined the second interview; one student was omitted from the analysis and not asked to participate a second time due to poor audio quality in the first stage recording.

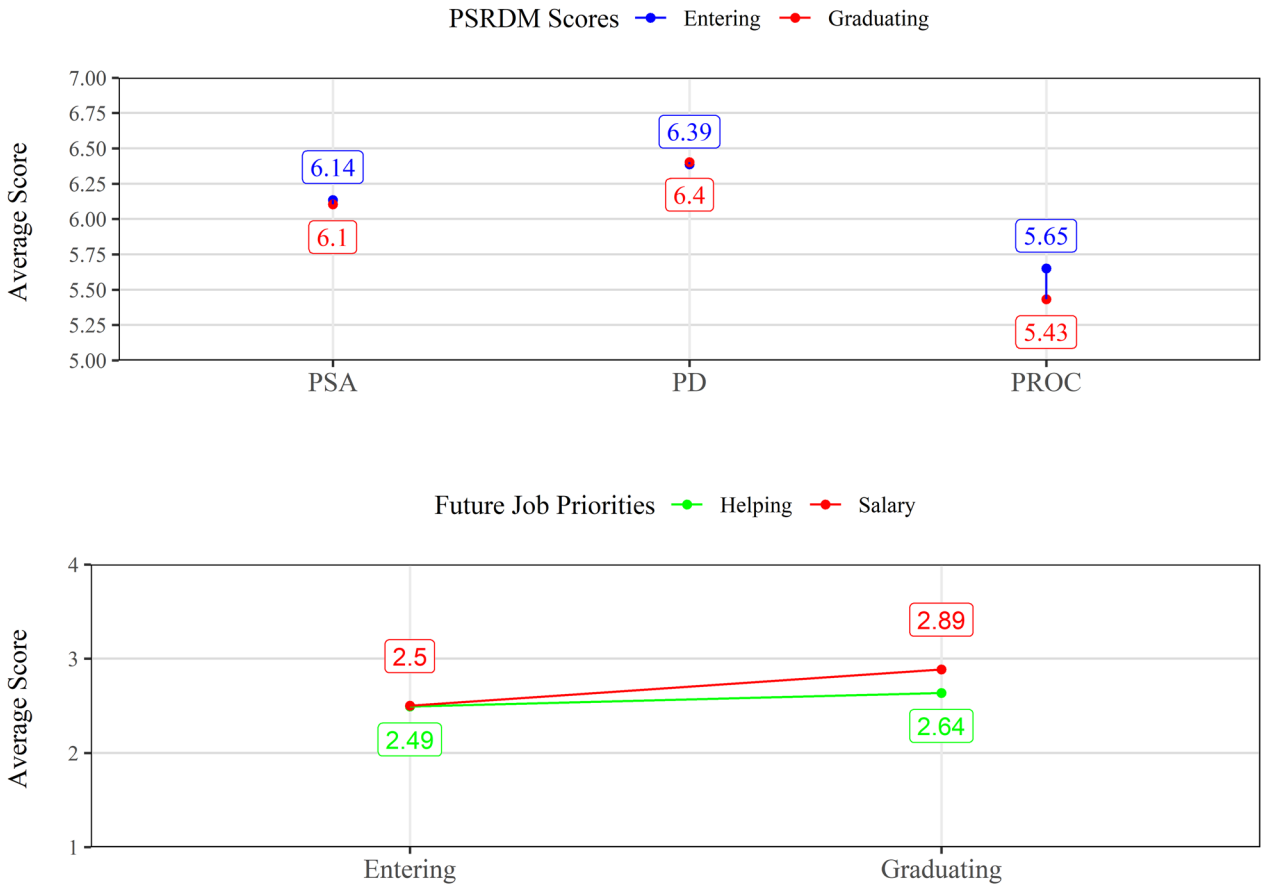

Fig. 2 Overall changes detected from the GPRA survey instrument in student social responsibility during undergraduate education ($n = 124$)

based on a non-parametric Wilcoxon signed-rank z test). The decline in PROC, as the theoretical culmination of the other two realms according to the PSRDM, is especially striking. This reiterates Cech's original concerns, a decade later, about social responsibility declines in undergraduate STEM education (Cech, 2013). Table 4 and Appendix Table A1 provide more detailed breakdowns of score changes, including for all 8 PSRDM constructs (Table A1) and for students who increased and decreased over time (both tables).

Other data from our study support this notion. For instance, during the survey, students were asked to place 10 stones into 8 buckets representing priorities underlying their future career choices. We paid special attention to two such categories in this stone sorting task as a proxy for whether social responsibility attitudes might be shifting: "Salary" and "Helping Others." For students overall, the average number of stones assigned to Salary grew (increase of 0.39 points, t (123) $= 2.83$, $p < 0.01$ based on paired sample t tests), while the average priority attached to Helping Others remained statistically flat (increase of 0.15 points, t (123) $= 1.10$, $p > 0.1$).

In short, the relative priority attached to a higher salary increased during undergraduate education more than for helping others through one's work. Note these findings partially contradict work undertaken in other countries, suggesting the importance of studying cross-cultural differences in student motivations (Forero & Gualdrón, 2024; Saari et al., 2024). They further urge the importance of longitudinal analysis to detect changes in students' relative priorities and help account for social desirability bias.

Yet qualitative data provide richer insights if not a slightly contrasting picture. For instance, during the researcher review of student transcripts and student summary memos, we identified that 13 of the 19 students who participated in both interviews experienced increases in SR development over time. However, 10 of the 13 students experienced only minor increases, and we identify these as relating primarily to social awareness.[7]

[7] Appendix F provides more detail about the approach taken to analyze student memos and make determinations.

We did find that students consistently became aware of certain societal issues, particularly those that were salient around the time of the interview. For example, while students in the first interview reported becoming more aware of student mental health—a prominent issue on campus at the time—in the second interview, students focused on issues like racial justice and the political environment in the US.[8] As one student noted:

> *"There's a lot of injustice in the world, especially from this past year. We can see that it's been exposed pretty heavily. I can fully admit that I was almost blind to all of it before, but now I'm more and more aware of how unfair some things are." (Male, Non-White, Mechanical Engineering)*

Another student reflected that, prior to college:

> *"I wasn't told these things. I was, you know, [I was] taught through the church to be a good person, and you know, not commit sins, or murder, or anything, but I wasn't taught, you know, about, you know, why are people homeless? Why is there such a big wage gap, you know?" (Female, White, Biomedical Engineering)*

Yet this growing awareness reported during the second interview did not translate into other downstream changes, such as a change in one's career path or perceived capacity to integrate SR into one's work. Particularly evident was that, as students proceeded toward graduation, their sense of self-efficacy about driving positive social change tended to decline, in some cases tied to experiences that occurred during summer internships. One student particularly invested in SR noted that:

> *"Even for me, it's sometimes a little bit hard to advocate for ethics...just because like company culture, it's all about money at the end of the day…I constantly have to make business cases for ethics…It's additional time, work, and effort on every project… it's going to be so much easier to do the easy thing." (Female, White, Music Technology)*

The decline in self-efficacy was felt so profoundly for one student that it even triggered a sense of cognitive dissonance:

> *"I guess I would say I'm probably a lot more cynical nowadays about just the tech industry in general than I was two years ago. And I suppose like my potential to impact it as well…It's like having two different identities, and…sometimes they don't really align like at the moral level kind of…[which] kind of creates some dissonance internally." (Female, Non-White, Computer Science)*

As a result, she conceded that SR activities were likely to remain only 'weekend' projects rather than deeply integrated into her core professional identity or work:

> *"I think I've come to understand that it's not easy to get those kinds of [social responsibility] opportunities, and—so what I realistically see is I'll probably explore those things as part of side projects or volunteering." Another student (Male, Non-White, Computer Engineering) put it starkly: "I think it's unfortunate you have to choose that dichotomy here. But yeah. That's the real answer."*

Overall then, despite promising student growth with respect to awareness of new social issues, we found that these learnings were unlikely to transform their career choices or their understanding of options within their profession to enact social responsibility. The interviewed students on the whole appear to stay on their pre-college path. For example, when asked directly about whether their mindset changed in college, a student summarized that:

> *"I would say I'm pretty similar. So I came into college a socialist. I'm leaving college a socialist…I would be really surprised if anyone comes into this college and comes out…thinking something different about… what their role in society is." (Male, Non-White, Computer Engineering)*

While this represents a lost opportunity even for students with a stronger prior interest in social issues, they may be able to retain their focus to some extent. In contrast, students *without* such a prior interest may have very few opportunities to incorporate SR into their professional identity without more careful planning and intervention by educational institutions. As one student put it:

> *"I didn't really get that in many places or aspects of my life and whose responsibility is it to teach me those things? Is it my own? How would I have even thought to seek those resources if something didn't spark it?" (Female, White, Biomedical Engineering)*

[8] Other topics included state or national elections, misinformation, the Covid-19 pandemic, environmental issues, and gender or sex-based discrimination.

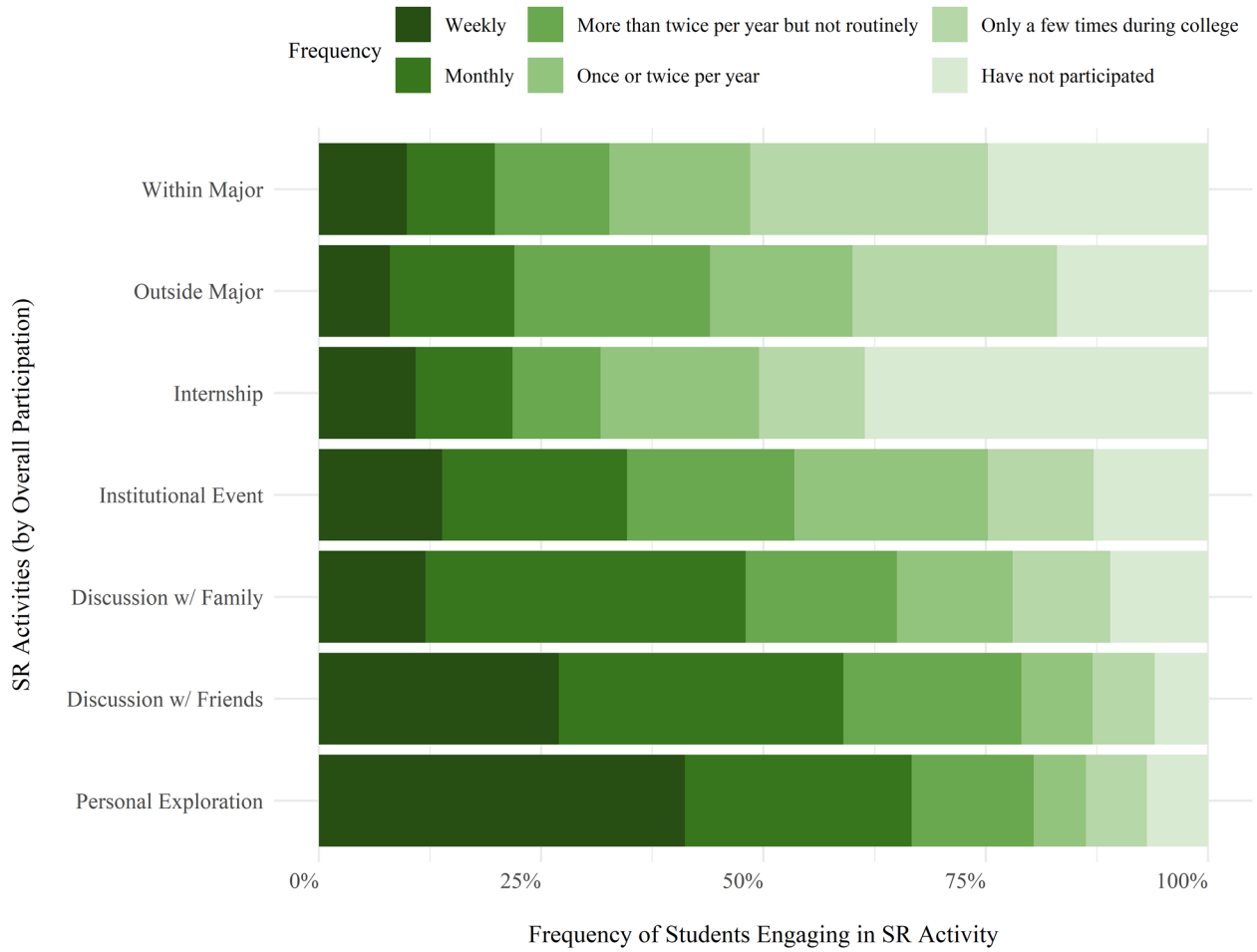

Fig. 3 Activities students engage in which involve social responsibility

Key SR activities, influences, and inhibitors: common SR activities

A second key question in our study is which activities supported the prospects of student development in SR.[9] In this paper, we focus on SR activities that took place during college, while prior work (Schiff et al., 2021) also reflects on pre-college activities. Figure 3 initiates the exploration by presenting the frequency of participation of students in a variety of SR activities, derived from seven associated questions in the survey instrument.

Overall, findings indicate that students engage most with SR issues as part of their own personal exploration (e.g., watching social media videos) and through discussions with friends and family. In contrast, students reported the least engagement with SR activities during formal coursework within their major or during professional internships. For example, 68% of students surveyed indicate at least monthly engagement with SR through personal exploration, and 59% through discussions with friends, while only 20% did so within their major and 22% within their internship. These findings suggest that much of student SR development happens outside of formal educational settings, and raises the concerning possibility that formal efforts are not especially prominent in driving SR.

A distinct but related question to frequency of engagement is which types of engagement are actually effective at influencing SR development. To get insights here, during the student interviews, we went into more depth by asking students to describe specific experiences on or off campus, ranging from academic to professional to personal experiences. We separately asked which influences

[9] Due to scope limitations, this paper focuses more on the particular *activities* that served as influences or inhibitors, rather than the deeper development process itself or individual student stories, though some of students' experiences can be gleaned from their quotes and the combination of their experiences. For more insight, however, we recommend perusing additional literature, such as Abe & Chikoko (2020), Batz-Barbarich et al. (2024), and Lathem et al. (2011).

most greatly affected both their sense of personal SR and professional SR, either positively or negatively. As part of the analysis process, we also determined whether students recalled the same set of influences between interviews; for example, if a student in the second interview did not reiterate that a certain course had been especially influential, we took that omission into consideration.

In this case, the quantitative and the qualitative evidence provide a highly commensurate picture.

Key SR activities, influences, and inhibitors: Qualitative findings

Importance of personal exploration, peers, and family. Most notably, the main activities that students engage in with some SR component are external to the primary offerings of universities. Many students mentioned that a lot of their personal growth came from exploring social media, watching documentaries, or reading books.

> *"A lot of it is through like YouTube which is interesting because YouTube is owned by Google. But it's kind of one of those things that like once I click on one YouTube video that's like explaining how Google and Facebook makes money, then just because of the algorithms that run YouTube all of a sudden they start pushing you more and more." (Male, White, Aerospace Engineering)*

Another student contrasted how her personal exploration was something she did 'instead of' school, drawing an explicit demarcation between school and service:

> *"I've been trying to educate myself more. I've been reading a lot of books. So I think I'm still figuring out, but I think I value the importance of [social responsibility] more. I'm making much more of an effort. I think before it was something that wasn't a priority, I put school first. (Female, White, Biomedical Engineering)*

Similarly, students frequently referenced friend groups and family as sources of conversations that changed their minds. As one student put it, they engaged with SR:

> *"…less so at Georgia Tech. More often, if I'm going to talk about that sort of thing, it'll just be with my family. Because my family is generally very active and has just a lot of familiarity with history and current events. If I'm going to talk, I'm generally going to talk with them." (Male, White, Aerospace Engineering)*

When referencing the impact of friend groups, often student clubs or Greek organizations, many students were influenced by exposure to diverse kinds of people as well as space to discuss and reflect.

> *"I think it's been really important because, you know, I think with the 60, 70 guys I'm just glad which we're having that many people, you're going to have different opinions, different experiences… literally just like hanging out with them around the lunch table like you're going to talk about different things and you're going to gain a new perspective on different…You're going to gain an appreciation for who they are as a person and maybe you wouldn't have otherwise and that's developing, that's becoming more socially aware." (Male, White, Aerospace Engineering)*

Another key source of influence was current events and news. During the time of the study, there was heightened attention to issues of racial justice, which had a significant impact on student social awareness.

> *"And then the change was, I guess, just over the summer. We all kept seeing it repeatedly on the news, and the defenses were building up. I think it kind of reached a tipping point, and then everyone started realizing how -- how big of an issue this was." (Male, Non-White, Mechanical Engineering)*

> *"Like the whole last summer like protests about BLM [Black Lives Matter] sparked a lot of like thoughtful conversations, that like definitely opened my perspective of like what is like social responsibility." (Male, Non-White, Industrial Engineering)*

Limitations of formal STEM coursework. In contrast, while 14 of 19 students interviewed were engineering majors, they identified little emphasis on SR as part of their main engineering coursework. For example, one student noted that there were "one or two" within-major courses from which she feels she "learned a great deal" about SR.

> *"I mean not all the classes I took were important to…grasping the aspect of social responsibility as a professional, but I would say those were definitely part of -- like the few classes I would say I actually learned from." (Female, Non-White, Computer Science)*

Beyond the occasional course in an engineering discipline, students identified non-STEM courses as generally having greater influence on SR development, often attributed to greater discussion of topics like ethics. Meanwhile, many students were critical of their STEM coursework. This was attributed to both lack of substantive coverage of SR issues and negative aspects of STEM culture, such as excess work, less flexibility, and less personal engagement with their professors.

"I've definitely heard it a lot more through like [non-major] things… where like, you know, I'm not -- if I show up to my CS…class, I'm probably not going to hear much. (Male, White, Computer Science)
"For the most part… we get taught a thing, and we pretty much leave. I don't think that we've ever really had some sort of like conscious discussion in one of my classes which I guess could be seen as a problem in itself." (Male, Non-White, Computer Engineering)
"I would say for majority, it would be not as much of an impact… Especially like my first and even some of my second year when I was learning core classes, I didn't really feel that much at all." (Male, Non-White, Mechanical Engineering)
"A lot of the courses I've been focusing on ever since then aren't the kinds of courses that lead themselves to easy community intervention." (Male, Non-White, Materials Science & Engineering).
"A lot of the professors aren't giving students the compassion they need to be people like with the harsh deadlines and just the rigidness and I think that shines out in the STEM disciplines versus the smaller classes that I've experiences in like [social sciences and humanities], the professors are more flexible, more personable and they have that more human element, which I think allows for the like internal growth, the comfort and safe space in class." (Female, White, Music Technology)

Views of institutional culture and student professional values. As a result, the majority of students suggested the institution was not excelling in its promotion of SR aims. We asked students to reflect on whether the university, as stated in its mission, helps deliver technological progress and/or promote social service. The bulk of students identified the former as a primary goal, whereas most identified service as only a minor goal:

"I don't think social responsibility plays into a lot of the aspects of being at Georgia Tech as a student." (Female, White, Mechanical Engineering).
"We're really good at building the next new thing and, you know, creating the next new technology and doing all these innovative things. But I think when we serve, we often look to far away places to serve... But I think Georgia Tech can do a lot better job of serving the communities at home and, you know, looking to find -- and looking to progress the community within and serve the community within a little more." (Female, Non-White, Literature)

Some of these values were reflected in student career preferences. One student suggested that his classmates' mindset emerges from the difficulty of pursuing STEM degrees, and other students articulated a substantial emphasis on career growth and salary. A common mindset was that students want to avoid working at companies they perceive as being "bad." However, they often drew ambiguous or permissive boundaries in terms of what that entails. Moreover, while they wanted to avoid companies with a bad culture or that were actively doing harm, seeking jobs with positive impact was often a secondary or tertiary goal.

"I put myself through absolute hell for four years to graduate from Georgia Tech…I want a job that I'll get paid more than anyone else and I do less work than anyone else. And in reality, most of the time that comes in when the company that you're working for is not focused on social responsibility because the reason why you get paid more to do less is because there's no focus on social responsibility." (Male, White, Mechanical Engineering)
"I think when I was looking for a job I was definitely focused on finding the job that would give me like the most valuable experience, and…that's more reputable. So I would say the job that gives more income, and that provides a better location…even though I tried [to emphasize social responsibility]…it definitely was not [a priority] if I'm being honest with myself." (Female, Non-White, Computer Science)
"You know, I guess doing good is like a lower priority for me but making sure I'm not doing bad is a high priority for me." (Male, White, Aerospace Engineering)

Key SR activities, influences, and inhibitors: Quantitative findings

One-at-a-time SR activity models. The quantitative analyses from the survey data support much of this picture. We separated SR activities into two camps for the purposes of data analysis: professional (four questions: institutional events, within major courses, outside of major courses, and internships), and personal (three questions: personal exploration, engagement with peers, and engagement with family). Overall SR refers to an aggregate measure of SR activities during college. After controlling for demographic variables (gender, race/ethnicity, college, American or international origin, first-generation status, and religiosity), we separately estimated how each individual SR activity predicted the three PSRDM components through OLS regression. In all models, we controlled for 'pre-college' PSRDM scores, measured shortly after starting college, to better measure changes over time.

Table 3 indicates that even when controlling for pre-college attitudes (Models 2 and 3), a variety of demographic factors (Models 2 and 3) and additional

Table 3 Results of multiple regression analysis predicting overall 2021 PSRDM scores: Overall SR

Variable	Model 1			Model 2			Model 3		
	B	SE B	β	B	SE B	β	B	SE B	β
Male	− 0.250	0.097	− 0.231*	− 0.026	0.083	− 0.024	0.025	0.080	0.023
White	0.042	0.099	0.038	− 0.065	0.082	− 0.060	− 0.081	0.077	− 0.074
Engineering Major	− 0.142	0.098	− 0.133	− 0.189	0.080	− 0.177*	− 0.165	0.076	− 0.154*
Country of Origin: USA	0.257	0.240	0.096	0.285	0.195	0.106	0.254	0.184	0.095
First Generation	− 0.327	0.303	− 0.095	− 0.519	0.247	− 0.152*	− 0.537	0.234	− 0.157*
Religious	0.066	0.096	0.062	− 0.073	0.080	− 0.069	− 0.021	0.076	− 0.020
PSRDM 2017	–	–	–	0.631	0.080	0.618***	0.535	0.080	0.524***
Comm. Engagement	–	–	–	–	–	–	0.001	0.001	0.091
Overall SR	–	–	–	–	–	–	0.002	0.001	0.232*
(Constant)	5.854	0.245	–	2.101	0.517	–	2.464	0.497	–
R^2	0.116			0.423			0.494		
F	2.571*			12.173***			12.384***		

* indicates $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$

community engagement experiences (Model 3), Overall SR activity scores are correlated with increased SR attitudes upon graduation. Results in all three models suggest, consistently, that attributes of students who majored in engineering and attributes of first-generation students are associated with lower graduating SR attitudes, while higher pre-college SR attitudes are highly correlated with higher SR attitudes upon graduation. In contrast, gender, race, country of origin, and religiosity are not significantly associated with changes in SR attitudes in the aggregate. Appendix Tables B1 and B2 present impacts of SR experiences on PSRDM scores in more detail, including when separated into Professional and Personal SR Activities. Demographic associations are similar to those reported in Table 3, and help to answer our third research question. Additionally, as another strategy to approximate causal effects of increased engagement in SR activities in the face of possible endogeneity, we perform a simple path analysis,[10] presented in Appendix C. We find that Overall SR, Personal SR, and Professional SR all have statistically significant effects, and are thus mediators between entering and graduating PSRDM scores.

Figure 4 presents the results, with significant coefficients indicated (see Appendix D for more details). Notably, we also observed that different types of activities affect personal social awareness and professional development separately. For example, the frequency of engaging in personal SR activities like discussions with peers or family and personal exploration had the greatest positive impact on the level of PSA at the time of graduation, controlling for pre-college PSRDM scores. On the other hand, the level of PD was significantly and positively impacted only by *professional* SR activities, such as institutional events, internships, and within major courses. Further, all seven individual SR activities were correlated with increased professional connectedness, though through different channels.[11] This provides some reassurance that the mechanisms of SR development occur in ways we might expect, buttressing the validity of the survey instrument and conceptual framework.

Aggregate professional and personal SR models. We also estimated how all personal SR and professional SR activities, when aggregated into only those two buckets, predicted PSRDM scores. This analysis choice is helpful because causal identification is difficult whether one employs multiple one-at-a-time SR activity models, or adds all activities into the same model. Any such modeling approach is imperfect, because many SR activities may correlate with each other and with unobservable underlying traits through complex chains over time. Tables D1 and D2 in the Appendix confirm that personal SR activities affect PSA significantly but not PD, and that professional SR activities affect PD significantly but not PSA.

[10] The purpose of this analysis is to identify whether SR activities during college have unique impact on 2021 PSRDM scores, or whether effects can be largely explained through only the direct impact of 2017 PSRDM scores (and the underlying factors that drove those original scores). Due to a small sample size of 124, we were limited in our ability to test effects for individual activities or to control for demographics through a more complex structural model. For these models, we average the three PSRDM domains and calculate an overall PSRDM score.

[11] Appendices B and C provide more details on the modeling strategy and results.

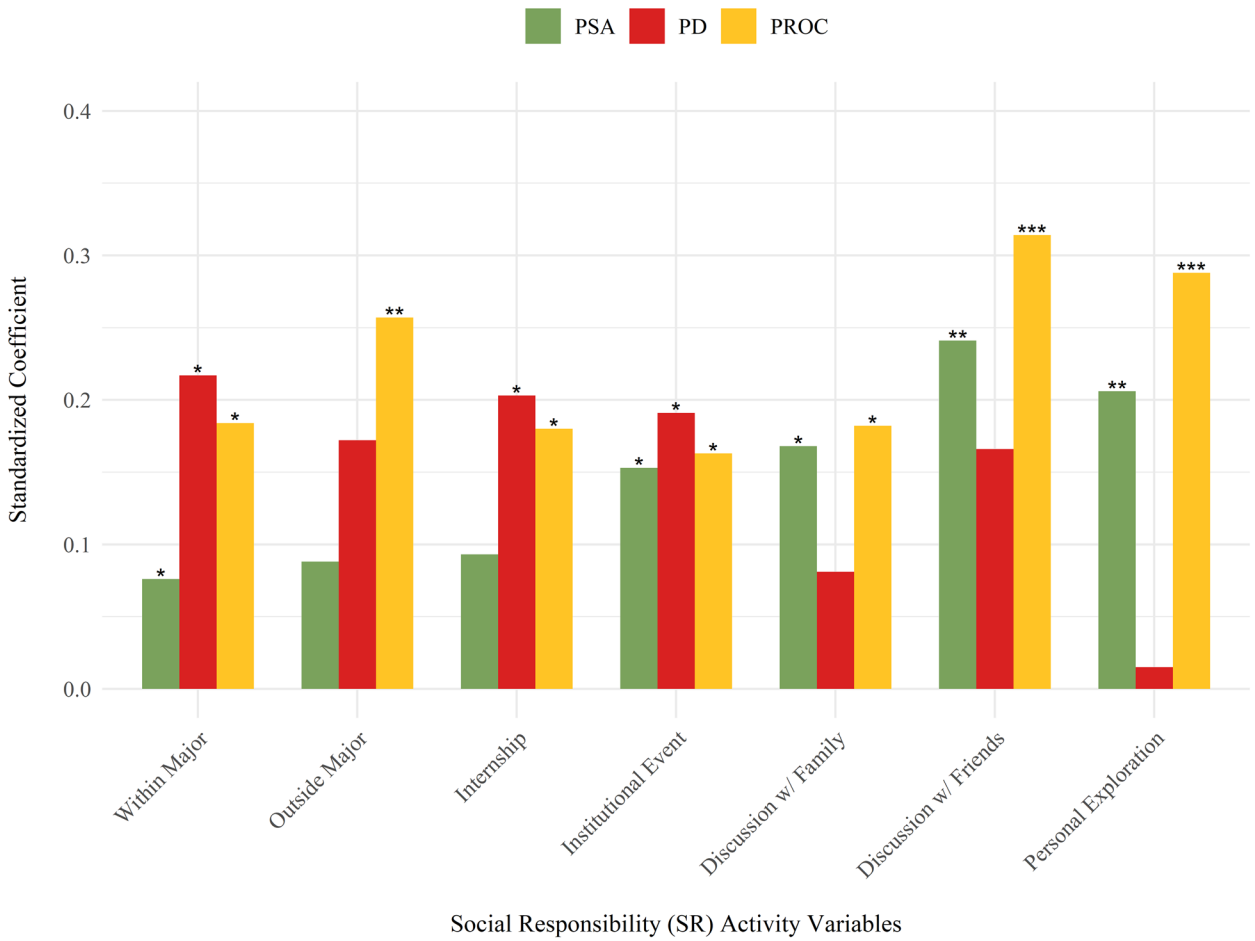

Fig. 4 Influence of SR activities on PSRDM realms from individual regressions. * indicates $p < .05$, ** $p < .01$, and *** $p < .001$

Table 4 Changes over time in PSRDM realms with student breakdowns

	Personal social awareness (PSA)	Professional development (PD)	Prof connectedness (PROC)	Overall PSRDM
Avg entering score	6.14	6.39	5.65	6.06
Avg graduating score	6.10	6.40	5.43	5.98
p value	.50	.81	<.001	.03
N students increased	55	54	45	50
N students decreased	66	50	76	74
N students unchanged	3	20	3	0

A Wilcoxon signed-rank test showed that there was a significant and negative change in PROC and PSRDM between entering-college and graduating-college scores. Totals may not sum to 124 in some cases given missing responses from some respondents

Influences for 'growers' and 'shrinkers.' Finally, to gain further insights, we examine patterns for students who increased or decreased (or remained flat) in their overall PSRDM scores (again an average of PSA, PD, and PROC domain scores). Among the total of 124 participants, 74 students had a decrease in Overall PSRDM scores between college-entering and graduating time points while the rest, 50 students, had an increase between the two time points. Interestingly, compared to those who decreased, those who increased more actively engaged in SR activities outside of their major (e.g., in an elective course or during an institutional

event outside of their department), t (122) = 2.123, $p <$ 0.05 (Table 4).[12]

We also examined whether students reported changes in their major or minor, and changes to their career path, resulting from their attitudes about SR. Compared to the shrinkers, the growers were likely to report stronger influence of concerns about SR on a change or addition to their major or minor at a marginally significant p value, χ^2 (1, N = 124) = 3.621, p = 0.057. Within the grower group, 24% reported that concerns about SR contributed to a change or addition to their major or minor while only 12% indicated as much within the shrinker group. This suggests, for example, that some students were inclined to switch majors or pick up a minor to meet their need to focus more on SR issues, a pattern we observed qualitatively as well with students who did not feel satisfied with or enjoy their STEM coursework.

However, in neither group did students report that concerns about SR led to a change in their future career plans. One interpretation of this finding is that students made some interim changes to their activities, such as which courses they take, but this did not ultimately translate into deeper professional changes, such as related to career intentions. This is consistent with some of our key findings. Students often do not receive enough explicit scaffolding as part of core institutional offerings like courses to help students identify and prioritize the SR dimensions of their future professional work. Thus, while students did exhibit increased awareness about some issues, and students who engaged more in SR had increased PSRDM scores by graduation, students overall arguably did not have enough exposure to these potentially powerful influences to produce more lasting professional changes.

Discussion, limitations, and conclusion

This study summarizes a five-year integrated mixed methods project tracking a cohort of undergraduate students at Georgia Tech. To our knowledge, this is the largest longitudinal study assessing social responsibility development for students from the start to end of their undergraduate education. This research is nevertheless subject to several key limitations. First, our quantitative sample is limited to 124 students who completed both administrations of the survey, and the sample is limited to undergraduates at one institution in one country, posing questions about generalizability. Second, the qualitative sample is limited to 19 students and our semi-structured interview approach could be subject to factors such as interviewer bias or variation (e.g., not asking each student the exact same set of questions). However, we did engage in several rounds of iteration, pilot testing, interviewer meetings, and inter-rater reliability testing during the coding process itself, and coders were randomly assigned to interviews.

Third, a core goal of this project was to assess the plurality of factors—positive and negative—contributing to student SR development or stagnation. However, such analysis is fraught because of the complexity of multiple interrelated factors over a long period of time; as such, we trade off the causal clarity possible with simpler pre-post studies for a more holistic if uncertain approach. Our results are also subject to other limitations common in qualitative and mixed methods research, including questions of researcher interpretation, differences between the composition of the quantitative and qualitative samples, and some discrepancies between qualitative and quantitative findings.

Nevertheless, over the five-year duration, this study and our time with the students led to several important findings both reiterating and extending prior research. Foremost, our findings reinforce prior research (Bielefeldt & Canney, 2016; Cech, 2013) cautioning that student SR attitudes tend to remain stagnant or decline over the course of undergraduate education. We find, for example, that student personal social awareness and professional development scores remain largely flat while average professional connectedness decreases between entering and finishing college. We further find that students tend to increasingly prioritize salary rather than helping others as they come closer to graduation. Our qualitative results suggest that while some students increase in terms of their general awareness of social issues, and some students even change their major or minor to better align with their SR values, these findings tend not to translate to overall professional connectedness or career decisions, especially as student self-efficacy to make positive change declines. SR education then, while leading to SR development for a minority of students, appears limited in its current form in STEM contexts and with respect to more enduring impacts.

Importantly, our longitudinal and mixed methods approach also allowed us to identify some ostensible causes, both positive influences and inhibitors. We largely find that SR activities and experiences that take place within the bounds of disciplinary education and STEM education especially tend to be rare and may contribute to decreased SR attitudes if anything. Recent research suggests that these discipline-based activities *can* be impactful if well designed (Cech & Finelli, 2024),

[12] We also considered creating an alternative clustering structure where only individuals with substantial increases (above the median) or decreases (below the median) are counted as having 'increased' or 'decreased' SR. This analysis confirms generally that individuals who increase in SR over time are engaged in more SR activities.

but our findings indicate there may yet be a long way to go. Further, while SR activities that take place outside of students' majors, institutional events, and internships might appear to be more promising, disciplinary education is more effective in improving the professional development domain of SR. This reiterates the need for both more common and more robust SR integration into the core of student disciplinary learning. We also found that student self-efficacy tends to decline over time, including after students participate in internships and realize the 'real-world' challenges they will face with SR, in contrast to the seemingly growing importance of other factors like salary. Better understanding the contours of career pathway decisions with respect to SR may be another important direction for scholars and practitioners to pursue (Abe & Chikoko, 2020). For example, critically interrogating internship experiences or hosting discussions on SR practice in real-world professional settings could help students develop more practical tools, ensuring that the impact of SR education efforts does not stop when one's career starts.[13]

In contrast to our findings on the major inhibitors, most of the positive influence in shaping SR development happened outside of core formal education, including through interactions with family members and peers, and personal exploration. Our findings especially highlight the importance of peer-oriented activities for social responsibility development, buttressing work on the importance of communal learning for social capital development and retention in STEM, including for first-generation students (Martin et al., 2020). There may be significant benefits for designing more communally-oriented programming in STEM education for maintaining interest, self-efficacy, and participation by women (Batz-Barbarich et al., 2024; Nalipay et al., 2024), in addition to SR development. Engaging peers as part of disciplinary and extracurricular activities could be an effective pathway to build SR by, for example, encouraging student activity leadership (Alpay, 2013) or engagement of alumni in helping students consider the SR dimensions of career decisions.

Our findings offer further utility for scholars with respect to conceptualization and measurement. They provide additional support for the benefits of the PSRDM as a conceptual framework, disentangling personal from professional development and understanding their interrelationships along the way to a professionally connected sense of social responsibility. Similarly, the GPRA appears to have meaningful predictive validity, including when administered over the duration of students' undergraduate educations. For example, we find that SR activities more closely aligned with personal and professional experiences, respectively, tend to correlate with increases in the personal social awareness and professional development dimensions of the PSRDM. We suggest that practitioners may likewise wish to approach the design of SR activities in an integrated and holistic fashion, cognizant of development outside of a single course or activity, and consider how SR growth may occur in a personal, professional, or combined sense.

A core goal and challenge of our study is the desire to assess impacts in a holistic and longitudinal fashion. Though this presents significant challenges for causal identification, we believe it is worthwhile and aimed to present a variety of analyses to buttress the alidity of our interpretations. For example, over-time changes controlling for pre-college attitudes, single SR activity correlations, path models, and triangulation with qualitative findings all helped us to draw an overall story. While these research designs remain less clean than single-semester interventions (Hwang et al., 2023), we think they are essential if we are to understand student pathways. Nevertheless, there may be other ways to isolate influences and inhibitors. Other scholars may identify different ways to parse and measure influences, perhaps through micro-reporting about influences, and should consider other statistical modeling strategies. Additional research unpacking student motivations, experiences, psychological processes, and more, are critical complements to this work as well. These methods can help assess the role of the wide range of activities and experiences that shape student SR attitudes before, during, and after college.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40594-025-00553-3.

Additional file 1.

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[13] See Schiff et al. (2021) for additional recommendations for educators and administrators.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Competing interests
The authors declare no competing interests.

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