Intervening on impostor phenomenon: prospective evaluation of a workshop for health science students using a mixed-method design

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Abstract
Background: Unaddressed impostor feelings that impede developing interest in science and self-efficacy in conducting research have a dispiriting effect that perpetuates unsatisfactory diversity in the health science workforce when such feelings are experienced more by those historically underrepresented in the workforce. This warrants effective interventions to reduce the impact of impostor feelings and related factors that diminish career resilience. We examined the effects of a 90-minute workshop on impostor perceptions and growth mindset to raise awareness of impostor phenomenon (IP) and develop skills to manage IP successfully for students attending a 10-week summer research experience program.

Methods: Using a convergent mixed-methods design, data were analyzed from 51 racially and ethnically diverse students who participated in an interactive IP workshop. Using students' half-way and final progress reports about their summer experiences and pre- and post-summer online surveys, we identified how the workshop changed awareness of IP and helped students develop coping strategies.

Results: Students strongly endorsed the workshop, remarking that its content and personal stories from peers validated their own IP experiences and relieved anxiety by revealing how common the experience was. Many reported applying mindset-changing solutions, including positive self-talk, focusing their thinking on facts about themselves and situation, and grounding themselves firmly against potentially persuasive and confidence-eroding impostor feelings. While students reported end-of-summer impostor feelings at levels similar to before the program, they described being able to manage their feelings better and persist towards goals and challenging tasks. One measure of IP appeared to be addressed through students' activation of a growth mindset, potentially explaining a specific mechanism for intervention. Discrepancies between qualitative responses and quantitative IP measures demand additional work on IP instruments.

Conclusions: A brief, theory-based IP workshop administered by research training programs, including those as short as 10-weeks, can have positive impact on subsequent IP experience and its successful management, with potential long-term impact on retention of a diverse biomedical research workforce.

Keywords: Impostor phenomenon, Growth mindset, Summer program, Intervention, Mixed-method
[1], with limited success. Many factors influence entry into training and education in STEM fields, as well as exit from it when career resilience and interest flag. Departing trainees from groups historically underrepresented in biomedical research further diminish diversity in research, and more emphasis on institutional culture change is needed [2]. Research education and training programs funded by the NIH play a major role in addressing this problem [3, 4]. These programs provide students considering medical school or graduate research programs with opportunities to explore science, conduct research with mentors serving as role models engaged in fulfilling work, have experiences that position them to explore science, conduct research, and regard failure as natural and instructive [21]. Recent decades of research have found that those with growth mindsets, where ability, skill, and performance on a task are viewed as acquirable through effort and practice; and a fixed mindset, where ability is viewed as a genetically derived, inherent and unalterable capacity [18–20].

Academic medicine has been suggested to foster self-doubt through conceptions of ability mindset [5], of which research has identified two major types: a growth mindset, where ability, skill, and performance on a task are viewed as acquirable through effort and practice; and a fixed mindset, where ability is viewed as a genetically derived, inherent and unalterable capacity [18–20]. Decades of research have found that those with growth (vs. fixed) mindsets adopt learning goals, seek challenging tasks, and regard failure as natural and instructive parts of the process of acquiring knowledge [21]. Recent work on IP and ability mindset [22] highlights the need to understand and intervene on factors related to trainees, their training environments, and factors that trigger impostor feelings, as these threats persist in clinical and research careers. Trainees considering careers in medicine and research, and those already committed to them both need to be able to strengthen their identities as scientists and clinicians, activate growth mindsets [23], manage perceived discrimination, including microaggressions [24], and cope with impostor feelings, as these may influence trainees’ sense of belonging in science and career resilience. Thus, recognizing the critical role of such skills in clinical and research careers and the need to master them is central both for recruiting trainees to the biomedical science workforce and reducing their departure from it. Delivering structured educational sessions to learn and practice managing and coping with such issues may be substantially better than relying on trainees to haphazardly acquire such skills themselves. To date, however, few evaluated interventions for managing IP are available [22, 25].

Given documented career benefit from participating in research during early career training [26–28], developing interventions to address IP early in training is urgent. We describe a brief interactive workshop to address impostor feelings and ability mindset delivered early in a 10-week, full-time, NCI/NIH-funded summer research experience program for college, graduate, and health professional students. We evaluated whether students improved their management of impostor feelings and used strategies to invoke growth mindsets, using both qualitative and quantitative evaluations. Specific questions were:

- Were there pre-post workshop changes in mean ratings for impostor feelings and growth mindset, and did changes differ by demographic groups?
- Were impostor ratings related to mindset ratings, and did the relationships change over time following the workshop?

We conclude with recommendations for developing interventions, delivered at critical junctures for career decisions and identity formation, to improve persistence in research careers in academic medicine.

**Method**

**Participants**

The University of Texas MD Anderson Cancer Center’s Cancer Prevention Research Training Program (CPRTP, www.CancerPreventionTraining.org/Summer) annually selects 25 nationally recruited undergraduate, graduate, and health profession students for mentored research experiences. The 10-week, multi-disciplinary program
exposes students to topics and research skills used in cancer prevention, including bench-based methods, qualitative and community-based methods, statistical and other quantitative methods, as well as professional development skills, and career exploration [29]. Activities culminate in a poster exposition and student elevator speeches at the end of the summer.

We analyzed data from 51 students in two summer cohorts (2018, 2019) that included 35 women (69%), 16 men (31%), 16 Asians (31%), 12 African Americans (24%), 6 Latinx (12%), and 16 Whites (31%). In addition to 24 (47%) college students were 7 (14%) medical students and 20 (39%) masters and doctoral students. Demographic data were collected in the online application to the summer program. For gender, the fields were labeled, “gender” with the response categories: female, male, other.

Ethics approval and consent to participate
This evaluation was approved as exempt and a waiver for informed consent was also approved by the Institutional Review Board (IRB) of The University of Texas MD Anderson Cancer Center (IRB #2020–0088 exemption).

IP workshop
Expanded from a well-rated 30-minute presentation about IP, the 90-minute workshop was designed to help students by anticipating common challenges when entering the professional research environment at MD Anderson. Delivered during orientation each summer, the workshop focuses on IP and the importance of expecting and embracing uncertainty as a necessary component of impactful research. Small-group activities, facilitated large-group discussions, and individual work fostered interaction between students and deepened development of IP coping skills.

The workshop (Table 1) begins with a 3-minute essay ("what does it mean for you to feel like an ‘impostor’?") and group discussion of the importance of “stupidity” and “failure” in research [30, 31]. These activities increase awareness about the role of these constructs in the scientific process with recognition of key but unspoken expectations or beliefs encountered or held by students during their transition from classrooms to research labs. This is followed by an introduction to IP and small group activities for students to practice identifying sources and triggers for IP, and then brainstorming strategies for coping with IP, which increases resilience by facilitating more rapid response to future IP challenges when they arise. After small group activities, groups share salient points in facilitated discussion with all students. The workshop concludes with discussion to define what “success” looks like (e.g., not a lack of failure) and the many qualities of successful scientists, using examples of Nobel laureates describing impostor experiences, and encouraging students to discuss why it is important to them or their peers.

| Workshop Section                                                                 | How the section is designed to achieve learning objectives                                                                 |
|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| What does it mean for you to feel like an “impostor”? (3-minute essay)           | Prime students’ mindset about IP; explain that researchers are trained to be pioneers and commonly feel different emotions, but the goal is to persist! |
| Doing research requires “stupidity” and “failure”                               | Acknowledge situations as possible opportunities for IP (i.e., acceptance into prestigious program with other highly achieving students); excellence in research requires embracing uncertainty; normalize feelings of “stupidity” and experience of failure and rejection as routine in science and research exploration, even beneficial and necessary to do impactful research. |
| Benefits of failure/rejection (individual brainstorm & share responses)          | Explore new perspectives of failure, rejection; guide them to derive benefit from failure, how to get the most from feedback; approach as process of learning. |
| Impact of impostor phenomenon (“why do we care about IP?”)                      | Define IP: group brainstorm activity to discuss why it is important to know about IP (connect with barriers to learning, goal achievement, career advancement). Students explain in their own words how IP might have impact on them or their peers. |
| Impostor phenomenon sources and triggers (small group activity)                 | To identify sources and triggers for IP, trainees share experiences and identify themes (evaluation/competition, prestigious programs, “high powered” researchers, experiencing success/seeing other trainee’s success). |
| Anti-impostor phenomenon strategies (small group activity)                      | Identify alternative approaches to sources/triggers they identified earlier to prepare for future IP experiences. [Acknowledge having areas for improvement does not mean being a fraud, being wrong or saying “I don’t know” isn’t catastrophic, know how common IP experiences really are, etc.] |
| 1) Re-define success for yourself, and 2) Qualities of successful scientists     | Students are challenged to recognize that being successful is not about lack of failure (citing “failures” from Nobel laureates). Ask trainees to define what they mean by research success (impact, advancing science, etc.). Encourage use of informational interviews to explore how senior researchers define success for themselves. |

Table 1  Research Success & Survival Workshop for Trainees during CPRTP Orientation
students to explore these issues with scientists encountered over the summer.

Measures and procedure
Data were collected from online surveys self-administered 2 weeks before and at the end of each summer, and half-way and final progress reports. Surveys included one adapted IP item from the Impostor Phenomenon Scale by Harvey and Katz [32] and two items from Leary's IP scale [33] and growth mindset items adapted from seminal work on mindset [20, 34]. The IP items were 1) “People tend to believe I am more competent than I really am,” (Harvey and Katz Item 1, dropping “in general” to allow reference to pre- and post-summer time points), 2) “I tend to feel like a phony,” (Leary Item 2), and 3) “Sometimes I’m afraid others will discover how much knowledge or ability I really lack,” (Leary Item 5). Ratings used Likert scales, ranging from 1 (not at all true of me) to 5 (completely true of me). The mindset items were 1) “Becoming a top, productive scientist is possible for everyone through effort and practice,” and 2) “Success in science is pretty much related to how much effort a person makes.” Ratings ranged from 1 (strongly disagree) to 5 (strongly agree). In the post-summer survey, students also reported experience of IP during the program and any coping strategies used. In structured progress reports, students wrote about the value of research, cancer prevention, personal growth, and career development from their experiences.

Analyses
We used a convergent mixed-methods design [35] to analyze and compare qualitative and quantitative data simultaneously. Qualitative phase. To gain a nuanced understanding of IP experiences, authors experienced in qualitative analysis (DC, HYL) independently reviewed trainee responses to open-ended questions in the surveys and text from progress reports [36]. Guided by the goal to evaluate workshop effectiveness, we identified key ideas related to IP by conducting a thorough content analysis of the text. After initially creating codes independently, we resolved coding disagreements and then iteratively constructed themes based on codes using constant comparison [37, 38] and analytic induction [39, 40]. Quantitative phase. For quantitative analysis, we used a series of repeated-measures ANOVA to examine changes in IP and ability mindset by gender, race/ethnicity, and academic rank. Alpha was set at 0.05. To allow comparison of effect size across the different measures, partial eta$^2$, where the effects of other independent variables and interactions are partialed out, was calculated for each of the dependent variables and are reported for significant effects [41]. All methods were carried out in accordance with relevant guidelines and regulations.

Results
Qualitative findings
IP manifested as (1) fear about asking for help; (2) comparison of self with others; (3) fear of lack of skills or experience; (4) self-doubt; and (5) uneasiness adjusting to new environments or new tasks, or both (Table 2). Some students recognized having IP experiences (e.g., “Since the workshop, I am better able to identify and acknowledge when I am feeling like an impostor”). Several reported working hard to overcome a potential root cause of impostor feelings: their fear of not knowing enough about their research. Notably, students reported experiencing IP when preparing and delivering elevator speeches and poster presentations, which were new activities for many. Reported by students to be “important,” these were “public performance experiences” for which they expected evaluation by mentors, colleagues, and others.

Many reported using workshop methods to deal with IP. For example, students reported implementing specific strategies to change their mindset: positive self-talk (e.g., “remind myself that I am [mostly] not here because of pure luck”); refocus of thinking on facts about themselves and the situation (e.g., “you’re here to learn [otherwise you would not be there in the first place]”; and recognizing and refuting impostor feelings (e.g., “I reminded myself that despite those feelings of doubt, there is little to negate the fact that my name is on that poster”). They also sought support from mentors, colleagues, and family, recognizing their ability to combat impostor feelings when knowledge gained from the workshop was reinforced during moments of struggle (e.g., “as I was preparing for my Elevator Speech, I felt a little nervous and my lab member reminded me that I am the expert of this project and I needed to own it.”).

Multiple benefits from the workshop emerged. In final progress reports, students reported that learning to deal with IP using specific strategies had impact on their career goals (e.g., “I frequently doubted intelligence and ability because I have not accomplished one of my life goals of becoming a physician. ... My self-confidence has been on a high and I feel like I can accomplish anything if I work hard and enjoy what I do.”). Students reported appreciating the opportunity to meet other students, working together on IP solutions during the workshop, and learning that having impostor feelings was common. They also valued scheduling the workshop during orientation to help them begin their summers successfully, viewing it as endorsement of its importance and the long-term usefulness of the content shared.
Table 2  Manifestations of IP

| Theme                                      | Quotations                                                                                                                                                                                                                                                                                                                                 |
|--------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fear about asking for help                 | “I definitely struggled getting accustomed to my lab and feeling comfortable asking questions and asking for help, which was definitely impostor syndrome because all of my lab members were extremely kind.”                                                                                                                                                                                                 |
| Comparison of self with others             | “I have a different career path than many of my peers in CPRTP. I am not as knowledgeable on many topics that my peers are well-rehearsed in due to my focused career path. This made me feel less valuable when discussing academic or social topics with my peers.” “…especially when talking about my project with my mentor since I feel like I actually don’t know anything compared to her. I’ve managed it by reading and informing myself more on the topic.” |
| Fear of lack of skills or experience       | “In laboratory, I had to learn how to do experiments for the first time, and throughout the summer, made many mistakes. This made me feel as though I was inherently incompetent.” “Sometimes I felt as if I could not perform the statistics necessary which made me feel like an impostor.”                                                                                                                                 |
| Having self-doubt                          | “I am always in these high-powered meetings where I sit and listen to presentations about results given by professors or postdocs and the discussion these create can go above my head and create feelings of ‘oh I’m not good enough for this kind of thing’ but then I realize, ‘wait a minute, I’m a grad student.”                                                                                         |
| Uneasiness adjusting to new environments or new tasks, or both | “Being at the largest, and best, cancer center in the country makes me feel that I am on a team bigger than myself, but it’s hard to feel like I belong here—which is probably coming from impostor phenomenon.” “…coming in, I was already wondering why I was picked over all the other qualified people who applied, not completely having a perspective to what people saw in me. The impostor syndrome presentation blew me away and brought a lot of thought to the forefront of my mind.” “…I have often felt this feeling of inadequacy in situations that I earned a position in, but never knew what this feeling was. Learning about the impostor phenomenon gave me the answer I was longing for. Also, learning that this phenomenon is so common gave me comfort that I am not alone, and gave me tools on how to combat and recognize these feelings before they come. Accordingly, I am getting more comfortable talking to the well-established and world-renowned doctors and faculty around the medical center. I now ask them questions that I may have never had the courage to before this program. This opportunity has also reassured me that I am going down the right path.” |

Quantitative findings

**IP, mindset changes over time**

Scores for IP items from pre-summer surveys indicated in general that student IP feelings were slight to moderate (Table 3). By gender, changes by end of summer in the IP1 and IP2 items were not statistically significant. However, for item IP3 “Sometimes I’m afraid others will discover how much knowledge I really lack,” an interaction between time and gender was statistically significant ($p = 0.01$, partial $\eta^2 = .14$); specifically, male students reported lower IP feelings and female students reported higher IP feelings after the program. For growth mindset measures, scores for “Success in science is pretty much related to how much effort a person makes” (GM2) improved significantly by the end of summer for all students, regardless of gender, race, or ethnicity ($p = .03$, partial $\eta^2 = .11$; $p_{FDR} = .049$, partial $\eta^2 = .09$), but there were no significant changes by student rank. No changes over the summer reached statistical significance for GM1 by gender, race, ethnicity, or student rank.

**IP, mindset relationships**

The expected significant correlations between the three IP items were found in both the pre- and post-summer surveys, as were correlations between the two growth mindset items, as shown in Table 4. In pre-summer surveys, two IP items (IP2 and IP3) were inversely related to the GM2 mindset measure ($r_{IP2} = -0.40$, $p < .01$; $r_{IP3} = -0.32$, $p < .05$). By the end of summer, the same correlations had weakened, rendering that between IP3 and GM2 non-significant ($r_{IP2} = -0.35$, $p < .05$; $r_{IP3} = -0.12$, $p > .05$); this occurred because GM2 scores had increased significantly without change in IP3 scores. This indicated that students’ increased endorsement in the mindset that scientific success relates to efforts made, but without change in their experience of fear of being discovered to have limited knowledge.

Disparities between qualitative and quantitative IP measures

We observed differences between quantitative measures of IP and qualitative comments about experiencing IP. In the post-summer survey, 19 participants (16 females) reported higher IP scores but described the usefulness of the workshop and their successful use of learned IP strategies, while 15 other students (9 females) reported lower IP scores and successful use of coping strategies. Two male students reported not having had previous IP experiences in open-ended responses, but reported relatively high pre-summer IP item scores (means = 3.6 – 4.7) and one female with relatively low IP scores before and after the program (mean for both = 1.7) reported deriving great benefit from the workshop: “Being accepted here at all gave me a huge amount of impostor feelings.... However,
Table 3  Pre- and Post-summer Mean (SD) Survey Responses for IP and GM Questions by Student Demographics

| Variable | IP1  | Pre- | Post- | p-value | IP2  | Pre- | Post- | p-value | IP3  | Pre- | Post- | p-value | GM1  | Pre- | Post- | p-value | GM2  | Pre- | Post- | p-value |
|----------|------|------|-------|---------|------|------|-------|---------|------|------|-------|---------|------|------|-------|---------|------|------|-------|---------|
| Female   |      |      |       |         |      |      |       |         |      |      |       |         |      |      |       |         |      |      |       |         |
| Male     | 2.50 | 2.29 | 0.99  | 0.53    | 2.64 | 2.22 | 1.04  | 0.08    | 2.30 | 2.55 | 1.06  | 0.01    | 3.88 | 3.82 | 0.68  | 0.04    | 369 | 381 | 0.78  | 0.03    |
| Hispanic | 3.14 | 3.00 | 1.29  | 0.38    | 2.29 | 2.22 | 1.04  | 0.08    | 2.30 | 2.55 | 1.06  | 0.01    | 3.88 | 3.82 | 0.68  | 0.04    | 369 | 381 | 0.78  | 0.03    |
| Black    | 1.83 | 2.25 | 1.29  | 0.53    | 2.64 | 2.22 | 1.04  | 0.08    | 2.30 | 2.55 | 1.06  | 0.01    | 3.88 | 3.82 | 0.68  | 0.04    | 369 | 381 | 0.78  | 0.03    |
| White    | 2.31 | 2.08 | 1.04  | 0.53    | 2.64 | 2.22 | 1.04  | 0.08    | 2.30 | 2.55 | 1.06  | 0.01    | 3.88 | 3.82 | 0.68  | 0.04    | 369 | 381 | 0.78  | 0.03    |
| Asian    | 2.53 | 2.93 | 1.03  | 0.53    | 2.64 | 2.22 | 1.04  | 0.08    | 2.30 | 2.55 | 1.06  | 0.01    | 3.88 | 3.82 | 0.68  | 0.04    | 369 | 381 | 0.78  | 0.03    |
| College  | 2.50 | 2.55 | 0.96  | 0.53    | 2.64 | 2.22 | 1.04  | 0.08    | 2.30 | 2.55 | 1.06  | 0.01    | 3.88 | 3.82 | 0.68  | 0.04    | 369 | 381 | 0.78  | 0.03    |
| Graduate | 2.16 | 2.32 | 1.20  | 0.53    | 2.64 | 2.22 | 1.04  | 0.08    | 2.30 | 2.55 | 1.06  | 0.01    | 3.88 | 3.82 | 0.68  | 0.04    | 369 | 381 | 0.78  | 0.03    |
| Medical  | 2.67 | 3.17 | 1.72  | 0.53    | 2.64 | 2.22 | 1.04  | 0.08    | 2.30 | 2.55 | 1.06  | 0.01    | 3.88 | 3.82 | 0.68  | 0.04    | 369 | 381 | 0.78  | 0.03    |

Significant effects (p < 0.05) are bolded. \( p_{\text{time}} \) = p-value of time effect, \( p_{\text{int}} \) = p-value of interaction effect between time and a predictor. IP1 = “People tend to believe I am more competent than I really am,” IP2 = “I tend to feel like a phony,” IP3 = “Sometimes I’m afraid others will discover how much knowledge I really lack.” GM1 = “Becoming a top, productive scientist is possible for everyone through effort and practice,” GM2 = “Success in science is pretty much related to how much effort a person makes.”
working through this program has given me a lot of confidence that has really put away a lot of those feelings."

**Discussion**

Although evidence on interventions that specifically address IP is lacking in the peer-reviewed literature, the development of structured training to help individuals avoid and manage IP threats successfully has been encouraged to prevent the long-term impact of impostor feelings [22]. In academic and professional training settings, such interventions could have a critical impact on trainee resilience and long-term commitment to pursuing research careers by helping them recognize barriers associated with IP and apply strategies to manage IP-related feelings effectively. Importantly, national efforts to foster a diverse STEM or health science workforce cannot be achieved if experiences of IP increase risk of departing from research career paths, especially for those from historically underrepresented groups. Our one-time, brief workshop delivered at the beginning of a summer research program for students helped them learn about IP and the commonality of its experience, and effectively influenced students’ growth mindset and appraisals of their IP coping ability.

A key finding was students’ successful use of strategies learned during the workshop. Quantitative analysis revealed stability in the low to moderate IP scores over the summer, with significant changes in only one measure of IP (IP3, lack of knowledge) by gender (females > males). However, students’ qualitative responses indicated increased ability to cope with IP through learned strategies, and the mechanism appeared to work through students’ activation of growth mindset. Specifically, students concerned about being exposed for their lack of knowledge appeared to have reduced such concern by the end of summer by endorsing a growth mindset about their ability. Importantly, we saw significant increases over the summer in growth mindset (GM2, success in science) for all students. Finally, we observed that qualitative comments did not always align with quantitative measures of IP indicating that sole reliance upon current IP instruments to identify those experiencing IP may not identify all such individuals, especially among diverse groups.

Our results suggest that interventions to address IP may be informed by the vast literature describing successful interventions for managing stress and anxiety [42, 43]. For example, cognitive reappraisal of stressors, which focuses on changing a person’s interpretation of the stressor and therefore changing the stress response (e.g., test anxiety as a performance enhancer vs. inhibitor [44]), has been of growing interest for intervention development and incorporated fixed/growth mindset orientations [45–47], also linked to risk of impostor fear [48]. Importantly, changes in mindset are associated with increases in coping with stressful events but not removing their threat [49]. Similarly, in our workshop evaluation, in spite of positive changes in mindset, impostor feelings remained stable or even increased, but improvement in coping with these feelings was documented.

A major strength of this evaluation was its mixed-methods design that used simultaneously collected qualitative perceptions of student IP experiences for comparison with quantitative metrics developed to measure IP [35]. Other strengths included embedding the workshop within a robust full-time summer research program and workshop effectiveness delivered

| Table 4 Correlations Between IP and Growth Mindset for Pre- and Post-Summer Survey Responses |
|----------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                                      | IP1    | IP2    | IP3    | GM1    | GM2    | IP1    | IP2    | IP3    | GM1    | GM2    | IP1    | IP2    | IP3    | GM1    | GM2    | IP1    | IP2    | IP3    | GM1    | GM2    | IP1    | IP2    | IP3    | GM1    | GM2    | IP1    | IP2    | IP3    | GM1    | GM2    |
| **Pre**                     |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| IP1                          | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| IP2                          | 0.48** | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| IP3                          | 0.43** | 0.74** | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| GM1                          | −0.03  | −0.22  | −0.01  | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| GM2                          | 0.07   | −0.40**| −0.32  | 0.39** | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| **Post**                     |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| IP1                          | 0.57** | 0.15   | 0.23   | −0.02  | 0.17   | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| IP2                          | 0.09   | 0.31   | 0.53** | −0.16  | −0.13  | 0.34** | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| IP3                          | 0.24   | 0.26   | 0.47** | −0.11  | 0.08   | 0.55** | 0.70** | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| GM1                          | 0.28   | 0.06   | 0.08   | 0.25   | −0.11  | 0.20   | 0.00   | −0.11  | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| GM2                          | 0.10   | −0.12  | −0.11  | 0.05   | 0.29   | 0.21   | −0.35* | −0.12  | 0.29** | 1      |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |

Significant correlations are bolded, *p < 0.05, **p < 0.01. IP1 = “People tend to believe I am more competent than I really am” IP2 = “I tend to feel like a phony” IP3 = “Sometimes I’m afraid others will discover how much knowledge I really lack”; GM1 = “Becoming a top, productive scientist is possible for everyone through effort and practice”; GM2 = “Success in science is pretty much related to how much effort a person makes”
once, for short duration, and for students diverse by race and ethnicity, gender, and rank. Also, the workshop used a variety of activities to complement didactic presentation of concepts and provide opportunity for students to practice generating strategies and consider how and when to apply them. Working together on these tasks was reported by students to help them engage with the concepts and with one another, thus enhancing their learning experience (Table 1). The project also had limitations. For example, even though the three items used to measure IP were taken directly from two well-known IP scales (i.e., the Harvey, the Leary), we were not allowed to administer the complete scales to establish convergent validity. In addition, since we considered this effort exploratory, we did not correct for multiple tests. Lack of anonymity may have suppressed IP scores in pre-summer surveys because students wanted to control self-presentation before beginning a prestigious summer program, rather than disclose vulnerability to IP. This speculation also supports the disparity we saw between qualitative and quantitative IP measures. Moreover, IP measures in the survey about the workshop at the end of the summer were likely influenced by the overall experience of completing the program. Also, because program leaders served as workshop instructors, student responses may reflect social desirability bias. Finally, the sample size was limited, prohibiting generalization of findings to subgroups.

Many recommendations result from this evaluation. Inconsistent alignment of qualitative comments with quantitative measures of IP calls for further development of tools to measure IP, including for individuals from different backgrounds whose experience may not be accurately characterized by available instruments. Focus should also center on measurement of the ability to manage impostor feelings, as changing the experience of IP may not be feasible to achieve from a short workshop over a brief time period. Exploring relationships between IP, mindset, and coping ability will yield important insight into the mechanisms of coping strategies and inform interventions for IP management and improve career persistence. The role of learning environments in activating IP warrants assessment. Previous research has depicted IP as a personality trait [50–52], but recent findings suggest that aspects of learning environments may increase IP vulnerability in addition to individual attributes [53]. For example, studies have shown connections between IP and workplace harassment, including sexism, sexual abuse, and micro-aggressions among female students and trainees in STEM [54, 55].

Conclusions
We designed and evaluated a brief IP workshop for students in a summer research program and found evidence that ideas and IP strategies from the workshop were used successfully by students. Many who experience IP are well-accomplished and successful, yet may have high risk for departure from research career paths due to insufficient skills for coping with IP. The implementation of this intervention in research training programs to minimize the impact of IP has promise for recruiting and retaining more research trainees and supporting broader diversity in the STEM and biomedical science workforce.

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Authors’ contributions
SC and MSY developed the study concept and design. Analyses were conducted by DC and HYL. Data were collected by KL, SC, and MSY. All authors (SC, HYL, CBA, KL, DC, MSY) wrote the main manuscript text and HYL, SC, and MSY prepared the tables. The author(s) read and approved the final manuscript.

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Availability of data and materials
Data from coded interviews can be made available upon written request to and approval by the corresponding author and co-authors.

Declarations
Ethics approval and consent to participate
This manuscript describes evaluation of an educational activity and is not considered human subjects research, so is not required to have IRB approval and consent to participate was not obtained from program participants. The study received a waiver of Ethical approval and informed consent that were fully approved by the Institutional Review Board (IRB) of The University of Texas MD Anderson Cancer Center (IRB #2020–0088 exemption).

Consent for publication
Not applicable.

Competing interests
To our knowledge, no conflict of interest, financial or other, exists for any of the authors on this manuscript.

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1. Not-OD-20-031: Notice of NIH’s interest in Diversity. Available from: https://grants.nih.gov/grants/guide/notice-files/NOT-OD-20-031.html.

2. McGee, L. Intervening structural racism in STEM higher education. Educ Res. 2020;49(9):633–44.

3. PAR-21-279: Cancer Research Education Grants Program - Research Experiences (R25 Clinical Trial Not Allowed). Available from: https://grants.nih.gov/grants/guide/notice-files/PAR-21-279.html.

4. PAR-20-066: Postbaccalaureate Research Education Program (R25 - Independent Clinical Trial Not Allowed). Available from: https://grants.nih.gov/grants/guide/pa-files/PAR-20-066.html.

5. LaDonna KA, Ginsburg S, Watling C. “Rising to the level of your incompetence”: what physicians’ self-assessment of their performance reveals about the impostor syndrome in medicine. Acad Med. 2018;93(5):763–8.

6. Haggins AN. To be seen, heard, and valued: strategies to promote a sense of belonging for women and underrepresented in medicine physicians. Acad Med. 2020;95(1):507–10.

7. Clance PR, Imes SA. The impostor phenomenon in high achieving women: dynamics and therapeutic intervention. Psychotherapy. 1978;15(3):241–7.

8. Chakravarty D. The impostor phenomenon among postdoctoral trainees in STEM: a US-based mixed-methods study. Int J Doc Stud. 2020;15:329–52.

9. Chakravarty D. PhD student experiences with the impostor phenomenon in STEM. Int J Doc Stud. 2020;15(1):159–80.

10. Lee H, Anderson CB, Yates MS, Chang S, Chakraverty D. Prevalence, predictors, and treatment of impostor syndrome: a systematic review. J Gen Intern Med. 2020;35(4):1252–75.

11. Hollday AM, Gheihan G, Cooper C, Sullivan A, Ohyama H, Leaf DE, et al. High prevalence of Impostorism among female Harvard medical and dental students. J Gen Intern Med. 2020;35(8):2499–501.

12. Levant B, Villwock JA, Manzano AM. Impostorism in American medical students during early clinical training: gender differences and intercorrelating factors. Int J Med Educ. 2020;11:90–6.

13. Villwock JA, Sobin LB, Koester LA, Harris TM. Impostor syndrome and burnout among American medical students: a pilot study. Int J Med Educ. 2016;7:364.

14. Leach PK, Nygaard RM, Chipman JG, Brunsvold ME, Marek AP. Impostor phenomenon and burnout in general surgeons and general surgery residents. J Surg Educ. 2019;76(1):99–106.

15. Sullivan JB, Ryba NL. Prevalence of impostor phenomenon and assessment of well-being in pharmacy residents. Am J Health-Syst Pharm. 2020;77(9):690–6.

16. Rosenthal S, Schlussel Y, Yaden DB, DeSantis J, Trayes K, Pohl C, et al. Persistent impostor phenomenon is associated with distress in medical students. Fam Med. 2021;53(2):118–22.

17. Lawton AJ, Lawton CW, Dietz SSB, Stevens EE, Weis JM. Exploring and managing the impostor phenomenon in palliative care: a case series. J Palliat. 2020;24(3):586–90.

18. Nicholls JG. Achievement motivation: concept of ability, subjective experience, task choice, and performance. Psychol Rev. 1984;91:328–46.

19. Dweck CS, Elfont ES. Achievement motivation. In: Mussen PH, Heatherington EM, editors. Handbook of child psychology: socialization, personality, and social development. 4th ed. New York: Wiley; 1983. p. 644–91.

20. Dweck CS. Self-theories: their role in motivation, personality, and development, vol. xiii. New York: Psychology Press; 1999. p. 195-xiii.

21. Dweck CS, Yeager DS. Mindsets: a view from two eras. Perspect Psychol Sci. 2012;11(1):1771.

22. Dweck CS, Elliott ES. Achievement motivation. In: Mussen PH, Heatherington EM, editors. Handbook of child psychology: socialization, personality, and social development. 4th ed. New York: Wiley; 1983. p. 644–91.

23. Bakke BM, Sheu L, Hauer KE. Fostering a feedback mindset: a qualitative systematic review and surgery. JAMA Surg. 2019;154(9):868–72.

24. Torres MB, Salles A, Cochran A. Recognizing and reacting to microaggressions in medicine and surgery. JAMA Surg. 2021;154(9):868–72.

25. Zanchetta M, Junker S, Wolf A-M, Traut-Mattausch E. “Overcoming the fear that haunts your success” – the effectiveness of interventions for reducing the impostor phenomenon. Front Psychol. 2020;11:405. https://doi.org/10.3389/fpsyg.2020.00405.

26. Jaffe DB, Yan Y, Andriole DA. Do research activities during college, medical school, and residency mediate racial/ethnic disparities in full-time faculty appointments at U.S. medical schools? Acad Med. 2012;87(11):1582–93.

27. Andriole DA, Klingensmith ME, Fields RC, Jaffe DB. Is dedicated research time during surgery residency associated with Surgeons’ future career paths? A National Study. Ann Surg. 2020;271(3):590–7.

28. Jaffe DB, Andriole DA. A study of U.S. medical graduates in internal medicine: research during graduate medical education and subsequent receipt of mentored-K awards. UI J 2018;6(1) https://www.understandinginterventionsjournal.org/article/3731-research-during-graduate-medical-education-and-mentored-k-awards-to-u-s-medical-graduates-in-internal-medicine.

29. Cameron C, Collie CL, Chang S. Introducing students to cancer prevention careers through programmed summer research experiences. J Cancer Educ. 2011;26(2):233–42.

30. Schwartz MA. The importance of stupidity in scientific research. J Cell Sci. 2008;121(11):1771.

31. Zare RN. The Virtues of Failure talk given at Paul Sabatier University in Toulouse, France to receive Honorary Degree. 2003 [https://zarelab.com/articles-presentations/the-virtues-of-failure-talk-given-at-paul-sabatier-university-in-toulouse-france-to-receive-honorary-degree/].

32. Harvey JC, Katz C. If I’m so successful why do I feel like a fake: the impostor phenomenon. New York: St. Martin’s Press; 1985.

33. Leary MR, Patton KM, Orlando AF, Wagener FW. The impostor phenomenon: self-perceptions, reflected appraisals, and interpersonal strategies. J Pers. 2000;68(4):725–56.

34. Jourden FJ, Bandura A, Banfield JT. The impact of conceptions of ability on self-regulatory factors and motor skill acquisition. J Sport Exerc Psychol. 1991;1:213–26.

35. Creswell JW, Plano Clark VL. Designing and conducting mixed methods research: SAGE Publications; 2017.

36. Coates WC, Jordan J, Clarke SO. A practical guide for conducting qualitative research in medical education: part 2—coding and thematising analysis. AEM Educ Train. 2021;6(4):e10645.

37. Glaser BG. The constant comparative method of qualitative analysis*. Soc Probl. 2012;54(1):436–45.

38. Glaser BG, Strauss AL, Strutzel E. The discovery of grounded theory; strategies for qualitative research. Nurs Res. 1968;17(4):364.

39. Pope C, Ziebland S, Mays N. Analysing qualitative data. BMJ. 2000;320(7227):114–6.

40. Thomas DR. A general inductive approach for analyzing qualitative evaluation data. Am J Eval. 2006;27(2):237–46.

41. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale: Lawrence Erlbaum, 1988.

42. Lazarus RS, Folkman S. Stress, appraisal, and coping. Springer publishing company; 1984.

43. Ivancevich JM, Matteson MT, Feederman SM, Phillips JS. Worksite stress management interventions. Am Psychol. 1990;45(2):352.

44. Jamieson JP, Mendes WB, Blackstock E, Schmarad T. Turning the knots in your stomach into bows: reappraising arousal improves performance on the GRE. J Exp Soc Psychol. 2010;46(1):208–12.

45. Jamieson JP, Crum AJ, Geyer JP, Marotta ME, Akinola M. Optimizing stress responses with reappraisal and mindset interventions: an integrated model. Anxiety Stress Coping. 2018;31(3):245–61.

46. Thomas DR. A general inductive approach for analyzing qualitative evaluation data. Am J Eval. 2006;27(2):237–46.

47. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale: Lawrence Erlbaum, 1988.

48. Glaser BG, Strauss AL, Strutzel E. The discovery of grounded theory; strategies for qualitative research. Nurs Res. 1968;17(4):364.

49. Pope C, Ziebland S, Mays N. Analysing qualitative data. BMJ. 2000;320(7227):114–6.

50. Thomas DR. A general inductive approach for analyzing qualitative evaluation data. Am J Eval. 2006;27(2):237–46.

51. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale: Lawrence Erlbaum, 1988.
S1. Langford J, Clance PR. The imposter phenomenon: recent research findings regarding dynamics, personality and family patterns and their implications for treatment. Psychotherapy. 1993;30(3):495–501.
S2. Dudău D. The relation between perfectionism and imposter phenomenon. Procedia Soc Behav Sci. 2014;127:129–33.
S3. Feenstra S, Beegy CT, Ryan MK, Rink FA, Stoker JL, Jordan J. Contextualizing the imposter “syndrome”. Front Psychol. 2020;11:575024.
S4. Aycock LM, Hazari Z, Brewe E, Clancy KBH, Hodapp T, Goertzen RM. Sexual harassment reported by undergraduate female physicists. Phys Rev Phys Educ Res. 2019;15(1):010121.
S5. Chakraverty D, Rishi M. Impostor phenomenon and discipline-specific experiences of violence in science, technology, engineering, and mathematics. Violence Gend. 2022;9(1):22–9.

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