Enhancing Medical Science Engagement through International Research Exchange: Objectives, Activities, and Outcomes

Monika Jürgenson[a], Andrea García-Llorca[b1], Anu Sarv[c2], Thor Eysteinsson[b], Miriam Hickey[a]*

[a]Department of Pharmacology, Institute of Biomedicine and Translational Medicine, University of Tartu, 19 Ravila Street, 50411 Tartu, Estonia.

[b]Department of Physiology, Faculty of Medicine, University of Iceland, Sæmundargata 2, 102 Reykjavík, Island

[c]Centre for professional development, University of Tartu, 36 Lossi St, 51003 Tartu, Estonia.

[1] Present address: Department of Neurobiology, University of Osnabrück, Barbarastrasse 11, 49076 Osnabrück, Germany.

[2]Present address: Centre for Learning and Teaching, University of Tartu, 36 Lossi St, 51003 Tartu, Estonia.

***Correspondence:**
Miriam Hickey, miriam.ann.hickey@ut.ee

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Abstract

The global decline in the number of physician-scientists, despite an increase in practicing physicians, underscores a critical need for integrating research training into medical education. Addressing this issue, we established an international research exchange program between the University of Tartu (UT) and the University of Iceland (UI). This initiative aimed to enhance scientific literacy, foster transferable skills, and align curricula with European standards through collaborative research experiences.

The program enabled reciprocal student mobility, involving 11 medical undergraduates (6 from UT, 5 from UI), who conducted month-long basic science research projects. Participants completed comprehensive pre-training in scientific communication, safety protocols, and ethics before earning 6 ECTS credits for fulfilling laboratory requirements and submitting final reports. Students were also required to participate in local public engagement events. Despite challenges and delays due to the COVID-19 pandemic, the program met its objectives, demonstrating adaptability and effective resource management.

Key outcomes included the development of an online learning platform, and multilingual guidelines and validated survey instruments to evaluate program impact, which we provide here to support similar initiatives. Feedback from pre-, post-, and post-1-year questionnaires revealed significant improvements in participants' confidence in research methodologies, critical appraisal of scientific literature, and motivation for future research involvement.

This project highlights the potential of structured international exchange programs to address gaps in medical education, enhance scientific training, and cultivate the next generation of physician-scientists.

1 Introduction

The number of physician-scientists is declining globally, despite the overall rise in the number of practicing physicians [1]. This concerning trend has prompted national and international organizations to advocate for increased engagement in research by medical professionals. For example, national guidelines in Canada and the United States encourage physician participation in research, while the 2024 draft of the UK's Good Medical Practice explicitly highlights research as a core skill within medical training [2–4]. Critical thinking and evidence-based approaches have long been recognized as fundamental skills for healthcare professionals, further underscoring the need to address this decline [5,6].

While several studies have shown the benefits of international exchanges for medical students, many primarily focus on the development of clinical skills [7–15]. Despite these efforts, barriers persist, particularly for undergraduate medical students. Surveys indicate that time constraints, a lack of appropriate research projects, and the exclusion of research from standard curricula remain significant obstacles [16]. Additionally, smaller countries face further challenges due to limited laboratory resources, expertise, and opportunities [17], hindering their ability to attract and nurture young talent in both medicine and research [17,18].

Participating in real-world, structured translational science projects has been shown to increase the likelihood of medical students engaging in subsequent research activities [19–21]. Moreover, international exchanges offer broad benefits for medical students, although most existing programs

focus on clinical skill development rather than basic science research. Programs like the International Federation of Medical Students Associations' (IFMSA) SCORE initiative highlight the potential of laboratory-based research exchanges to complement medical education by fostering critical thinking, technical skills, and global awareness.

Recognizing these gaps and opportunities, we established a research exchange program between two partner universities aimed at undergraduate medical students. By facilitating month-long, hands-on research projects, this initiative provided students with practical exposure to basic science, enhanced transferable skills, and enriched the academic curricula of both institutions. The program also aligned with the Bologna Process goals, fostering international collaboration and strengthening the competitiveness of the participating universities.

Through careful planning and execution, the program addressed common barriers to student participation in research. It included pre-training in communication, safety, and ethics, and required students to complete all laboratory hours and submit detailed reports to earn academic credit. This model not only ensured rigorous academic standards but also created a framework for mutual learning and cultural exchange.

The outcomes of this program underscore the potential of structured international research exchanges to enhance medical education. By fostering a deeper understanding of science and its applications, such initiatives can play a crucial role in reversing the decline of physician-scientists and preparing the next generation of healthcare professionals to meet the challenges of modern medicine. Based on our experience, we also propose practical guidelines for establishing similar programs to broaden their impact and reach (Practical Guidelines for Organizing International Research Exchanges; Supplementary materials 4).

2 Materials and Methods

2.1 Participants and Ethical Considerations

Medical undergraduate students from the University of Tartu (UT) and the University of Iceland (UI) were invited to participate in an exchange program designed to conduct month-long basic science research projects ("research miniprojects"). Ethics approval for the program was granted by the University of Tartu (approval number 361/T-8). Participation in feedback was voluntary, and students provided anonymous feedback through three questionnaires administered at different stages of the program. The program was conducted in 2019-2023. For experiments involving animals, all necessary ethical approvals were obtained from local authorities before the students' arrival.

2.2 Program Design and Online Learning Platform

A dedicated online learning platform was created within the UT Moodle space to support the participants. The platform provided: general program information; introductory details about faculty members; mandatory training modules on laboratory safety, research animal ethics, and communication skills; background information on research projects, including updates reflecting new data as the projects evolved; templates and guidelines for progress and final reports; resources on open science practices and information about the transnational conference. All students completed required quizzes and signed Laboratory Safety Guidelines before travel. Training on research animal

ethics was mandatory for all participants, along with two academic hours of communication training focused on addressing diverse audiences, including peers, senior faculty, and the public. Finally, all students were required to participate in local public education events.

2.3 Research Miniprojects

Each student participated in an individual research miniproject as part of the exchange program. During these exchanges, students from the University of Tartu (UT) conducted research in the Department of Physiology at the University of Iceland (UI), while students from UI carried out their projects in the Department of Pharmacology at the Institute of Biomedicine and Translational Medicine, UT.

The program was implemented in two phases. For the 2022 exchanges, students explored diverse research topics, including retinal degeneration, obesity and cognitive performance, Alzheimer's disease, Wolfram syndrome, and Parkinson's disease. In 2023, the focus shifted to retinal morphology, retinal function, and lysosomal function in rare disease models. This well-structured exchange fostered collaboration and contributed to advancements in very different biomedical fields. Data collection and feedback mechanisms were also incorporated to evaluate the program's outcomes and improve future implementations.

2.4 Data Collection and Feedback Mechanism

Feedback from participants was collected via three questionnaires: a pre-program questionnaire: administered before the research exchanges to assess expectations and preparedness; a post-program questionnaire: administered immediately after program completion to evaluate satisfaction, challenges, and outcomes; and post-1-year follow-up questionnaire: designed to assess the long-term impact of the program on participants' academic and professional development. Exact questionnaires are presented in supplementary materials (Supplementary materials 1, 2 and 3). Participants completed a pre-questionnaire before engaging in laboratory-based practical training. Participants assessed their competency levels across multiple domains using a five-point Likert scale (Poor, Fair, Average, Good, Excellent). The evaluated skills included laboratory skills such as technical scientific skills and critical assessment of scientific publications, as well as transferable skills such as time management, organizational skills, teamwork abilities, leadership skills, communication skills, and scientific report writing. Following the completion of the laboratory module, the same questionnaire was administered to measure any changes in self-perceived competencies and perspectives. Furthermore, participants provided feedback on the overall impact of the program, offering insights into their perceived personal and professional development.

2.5 Evaluation Tools and Metrics

The evaluation included the following: progress and final reports prepared by participants, which were reviewed and archived; structured feedback through questionnaires to assess the efficacy of the program's design, resources, and impact; learning outcomes evaluated through mandatory training completion and laboratory performance during research exchanges. All data were analyzed as changes in laboratory skills, transferable skills, and satisfaction and impact of the program from students' point of view.

2.6 Resources and Accessibility

The Moodle learning platform hosted all information and was accessible to all participants using the credentials provided. Key resources included templates for mandatory forms, video lectures, and training modules. Additional materials were linked to the main program page and Moodle site, ensuring accessibility for participants.

2.7 Challenges and Adaptations

The global COVID-19 pandemic caused delays in program initiation, necessitating adjustments to project designs and timelines. Despite these challenges, all students successfully completed their research projects, producing high-quality data and reporting high satisfaction levels with the program.

2.8 Statistical analysis

Statistical analyses and graphical presentations were performed using GraphPad 9.4.1 (San Diego, CA, USA). All responses from student participants were considered when interpreting the results. In the pre-program questionnaire, 10 out of 11 students responded. The post-program questionnaire received responses from 9 out of 11 students, while the one-year follow-up questionnaire had 4 responses out of 11. Data sets were analyzed using Fisher's exact test, with statistical significance set at $p < 0.05$.

3 Results

3.1 Laboratory skills

As presented in Figure 1A, participation in the program led to a significant improvement in technical scientific skills. The feedback-based assessment demonstrated a statistically significant enhancement in technical science skills ($p<0.0001$, Fisher's exact test). A clear improvement was also observed in the critical assessment of scientific publications, as shown in Figure 1B. The findings suggest that practical laboratory training contributes positively to skill development and professional identity formation in aspiring physician-scientists.

3.2 Transferable skills

As presented in Figure 2, participants initially rated their transferable skills within the range of fair to good. However, working in teams and communication skills (Figure 2C and E) were the only areas where they considered themselves more proficient even before the program. Nevertheless, the post-questionnaire results show, as illustrated in Figure 2, a clear improvement in time management, organizational skills, teamwork abilities, and leadership skills. Moreover, as depicted in Figures 2E and 2F, statistically significant improvements were observed in communication skills and scientific report writing ($p<0.05$ and $p<0.01$, respectively, Fisher's exact test).

3.3 Overall opinion

We also asked participants to provide feedback on the overall impact of the program to better understand their perceived personal and professional development. As shown in Figure 3, students reported significant improvements in their understanding of how scientists tackle real-world problems, the importance of evidence in science, ethical conduct in the field, and increased self-confidence (Figure 3A, C, D, E). There was a more modest gain in their sense of contributing to the body of knowledge. This outcome is understandable, as undergraduate students may find it challenging to grasp all aspects of a foundational science project. Additionally, since the program involved a mini-project, completing it highlighted how much more there is to learn. Overall, participants reported feeling moderately to very satisfied at the end of the program (Figure 3F).

3.4 Long-term impact of the program

A one-year follow-up questionnaire was conducted to evaluate the program's long-term impact on participants' academic and professional development. We received four responses: one participant is conducting a research project as part of their degree, while two are engaged in volunteer work—one of whom may transition into a degree-required project.

4 Discussion

Medical curricula are increasingly incorporating case-based learning to enhance relevance and real-world training [22]. Most international electives available to medical students focus on clinical skills, while opportunities to develop laboratory and basic science skills remain limited. This is despite national organizations actively supporting and encouraging research training initiatives [2–4]. Globally, physician-scientists face unique challenges in securing funding and training, leading to high attrition rates in sustaining a career that integrates both medicine and research [17]. To mitigate this issue, some countries have introduced paid research training programs for medical graduates [17].

Surveys among undergraduate medical students indicate that barriers to engaging in research include time constraints, limited availability of suitable projects, and a lack of integration into the curriculum [19]. However, those who do participate generally report positive experiences [23]. For smaller universities, international research exchanges offer significant benefits by expanding access to research opportunities and enhancing technical training. These programs also provide valuable transferable skills, such as proficiency in a common foreign language (English, in our case), aligning with the EU Recommendation on Key Competences for Lifelong Learning (2018/C 189/01). Additionally, such exchanges contribute to curriculum enhancement and support the Bologna Process by fostering student mobility and transnational collaboration (EU Bologna Process).

Our findings demonstrated significant improvements in laboratory and scientific skills among participants. Moreover, participants demonstrated improved critical assessment of scientific publications, highlighting the program's impact on developing analytical skills crucial for physician-scientists. Beyond technical skills, the program had a considerable impact on students' transferable skills, as the post-program assessment revealed marked improvements in time management, organization, teamwork, and leadership, while communication skills and scientific report writing showed statistically significant gains. These findings suggest that hands-on research experience fosters essential skills beyond the laboratory, preparing students for interdisciplinary collaboration and effective scientific communication. A one-year follow-up questionnaire was conducted to evaluate the program's long-term impact on academic and professional development and although out of the 11 eligible respondents, four provided feedback, they were all involved in science, whereas

one participant was actively engaged in a research project as part of their degree. These results suggest that the program had a lasting effect on participants' academic and professional trajectories, reinforcing the value of early exposure to research opportunities.

While our findings highlight the benefits of international research exchange programs, some limitations must be acknowledged. First, the sample size was relatively small, which may limit the generalizability of our results. The number of participants decreased in the follow-up questionnaires, reducing the ability to assess long-term impacts comprehensively. Additionally, self-reported data may introduce response bias, as students might have felt inclined to provide positive feedback.

Another limitation relates to variations in participants' prior research experience. Differences in baseline skills may have influenced the degree of improvement observed, making it challenging to precisely quantify the program's impact on individual skill development. Additionally, the short duration of the exchange (one month) may not have been sufficient for students to gain in-depth research expertise comparable to longer-term programs. Logistical challenges also posed limitations. Although the program covered all expenses, accommodation costs varied between institutions, particularly since travel was most feasible during the summer months. Differences in accommodation costs, access to laboratory facilities in the host country, and funding disparities between partner institutions may have influenced the overall experience for some students. Additionally, external factors, including the COVID-19 pandemic and geopolitical instability, impacted program implementation and potentially influenced application rates. Despite these limitations, our study provides valuable insights into the potential of international research exchanges to enhance scientific training and skill development for medical students. Future programs could benefit from larger sample sizes, extended study periods. Indeed, here we provide guidelines based upon our experiences, to support similar future programs.

Overall, our findings highlight the significant benefits of international research exchange programs, offering hands-on research experience, strengthening both technical and transferable skills, and fostering global collaboration. Importantly, our results demonstrate how smaller EU border countries can collaborate to provide enhanced opportunities for students while equipping them with critical technical and transferable skills valued by international medical organizations. Many exchange programs are available within the EU. In particular, ERASMUS schemes are very well known and are very valuable for students and faculty alike. However, our program emphasized, specifically, collaboration between smaller countries, with a focus upon exposure to basic science. Addressing logistical challenges, ensuring structured training and supervision, and integrating participant feedback are essential for the continued success and expansion of such initiatives in the future

5 Conflict of Interest

6 Author Contributions

Monika Jürgenson: Writing – review and editing, interpretation of results, conceptualization, supervision and funding acquisition Andrea García-Llorca: Writing – review and editing, interpretation of results, supervision. Anu Sarv: Preparation of questionnaires, interpretation of results, conceptualization. Þór Eysteinsson: Writing – review and editing, interpretation of results, conceptualization, supervision, funding acquisition. Miriam Hickey: Writing – review and editing, interpretation of results, conceptualization, supervision, resources, and funding acquisition.

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Figure legends

Figure 1. Laboratory skills

The effect of the program on laboratory skills of the participants.

(A) Technical science skills. **** $p < 0.0001$; Fisher's exact test; (B) Critical assessment of science publications. Number of participants Pre-questionnaire: n =10; Post-questionnaire: n = 9.

Figure 2. Transferable skills

The effect of the program on transferable skills of the participants.

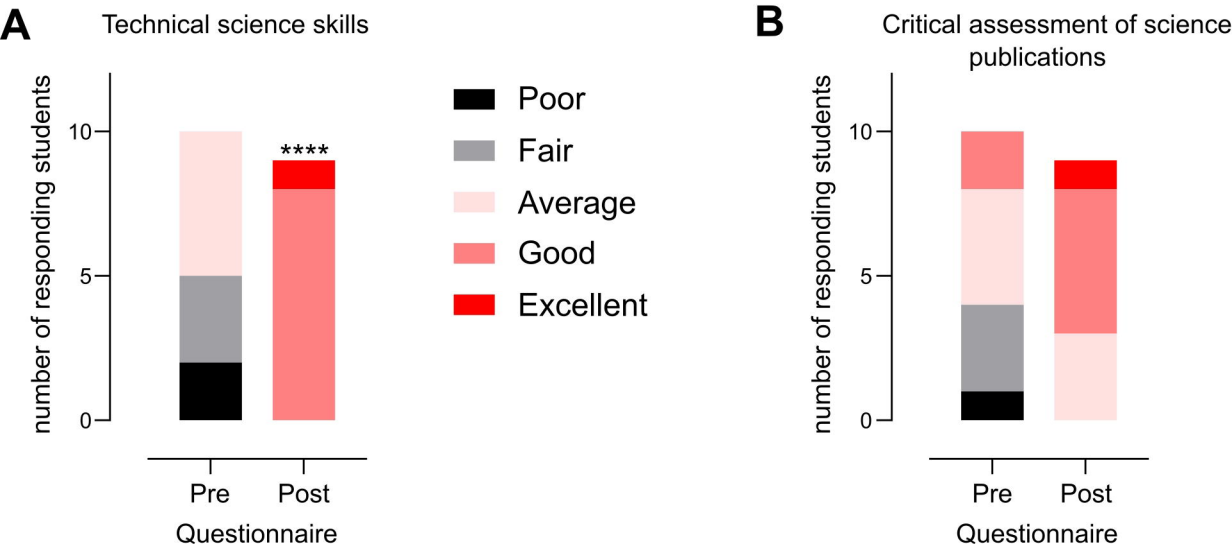
(A) Time management skills; (B) Organizational skills; (C) Teamwork skills; (D) Leadership skills; (E) Communication skills. * $p < 0.05$; Fisher's exact test; (F) Scientific report writing skills. ** $p < 0.01$; Fisher's exact test. Number of participants Pre-questionnaire: n =10; Post-questionnaire: n = 9.

Figure 3. Students overall opinion on the impact of the program

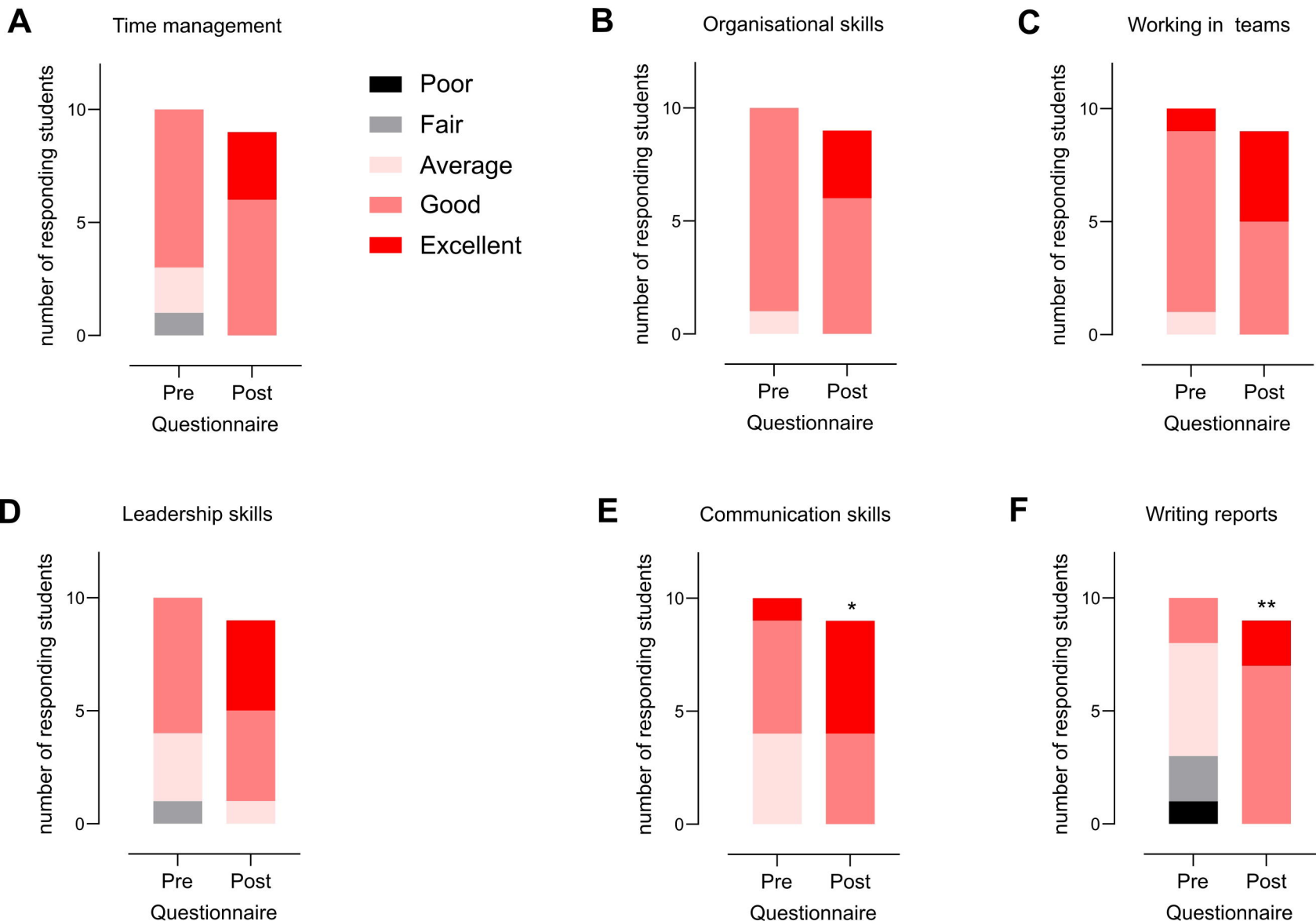
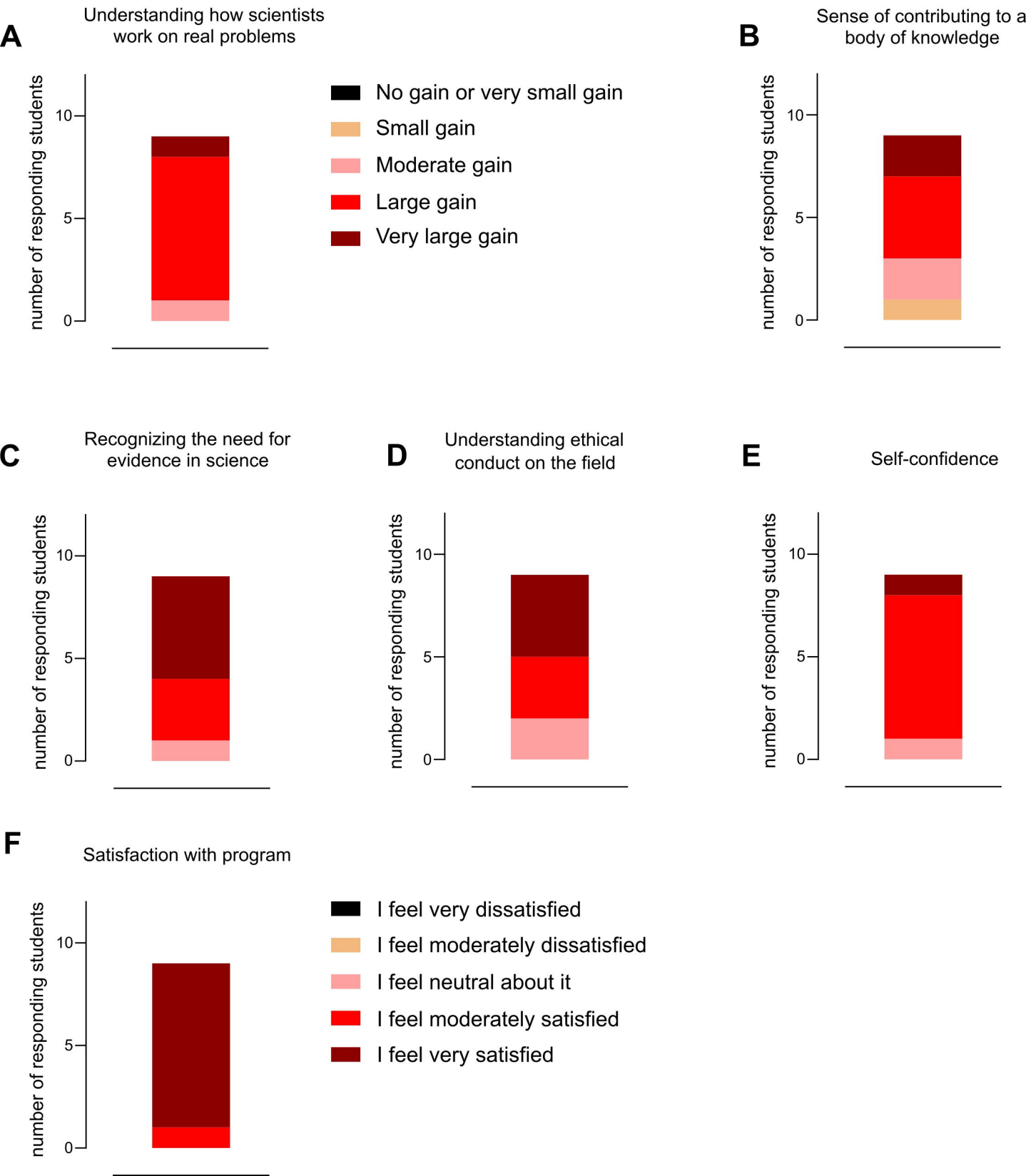
Students overall opinion on the impact of the program.

(A) Understanding of how scientists work on real problems; (B) Sense of contributing to a body of knowledge; (C) Recognizing the need for evidence in science; (D) Understanding ethical conduct on the field; (E) Self -confidence; (F) Satisfaction with the program. Post-questionnaire: n = 9.

Laboratory skills



Transferable skills



Students' overall opinion on the program's impact