Why Engage in Scientific and Technological Initiation?
A Groundbreaking Brazilian Study

Woska Pires da Costa, Instituto Federal Goiano, Brazil
Angélica Ferreira Melo, Instituto Federal Goiano, Brazil
Priscilla Rayanne E. Silva, Instituto Federal Goiano, Brazil
Matias Noll, Instituto Federal Goiano, Brazil

The Paris Conference on Education 2024
Official Conference Proceedings

Abstract
Scientific and technological initiation programs are developed to introduce students to scientific research and technological development. Our study aimed to evaluate undergraduate students' research experience, self-perceptions, and scientific production during one academic period. The study design was based on quantitative analysis of curricula vitae, and an electronic survey was conducted on students enrolled in a Brazilian Midwest Institute. The sample included 213 students (115 female, 54.0%) who participated in a Brazilian undergraduate program (UR) – called Scientific Initiation (SI) – during the 2018–2019 academic term. The students were divided into two groups according to their experience in research: 110 (51.6%) students were experiencing their first time in a research program, and 103 (48.4%) experienced students. The results showed that students who had participated in research activities more than once perceived the benefits of SI more positively ($p=0.047$) and demonstrated a greater volume of academic production than those who were participating for the first time ($p<0.001$). Both groups agreed that experience in SI will contribute to better academic performance in graduate programs (novices: 64.5%; experienced: 71.8%). Furthermore, most participating students expressed their intention to continue their involvement in SI (novice: 59.1%; experienced: 64.1%), indicating the positive trajectory of Brazilian SI programs. In conclusion, undergraduate students who participate in UR programs, as in Brazilian SI programs, contribute positively to academic production and training by providing personal and professional benefits and the opportunity to produce academic work that can help initiate academic careers.

Keywords: Academic Development, Academic Production, Scientific Initiation, Undergraduate Research, Student Perceptions

Introduction

Scientific research in the academic environment is crucial to a country's progress, and educational institutions are responsible for promoting and facilitating this process (Zheng, 2023). From this perspective, encouraging research is essential for advancing scientific knowledge and promoting technological innovation (Chen, 2021). One proven effective mechanism is public policies such as undergraduate research programs (UR). These programs play a crucial role in students' academic and professional development, and it is within the power of educational institutions to enable them to become future researchers and scientists (Daniels et al., 2016). Furthermore, when students are involved in scientific research and technological development from an early age, a nation can reduce its dependence on other countries. Therefore, it is crucial for educational institutions to actively involve students in the UR by promoting these programs through outreach and leveraging digital and social media platforms (Mahatmya et al., 2017).

Several countries have been increasingly committed to promoting programs that provide students with enriching experiences in science and technological innovation. For example, in recent decades, funding agencies in the United States have diversified programs focused on Science, Technology, Engineering, and Mathematics (STEM), resulting in successful academic UR initiatives aimed at underrepresented college students (Hernandez et al., 2018). New Zealand is also an example of this movement, where research has become an increasingly relevant component of undergraduate studies, benefiting students by providing a wide range of developmental skills (Lopatto, 2010; Mantai et al., 2023; Mieg et al., 2022).

In the context of Brazil, UR programs are designed to involve students in scientific and technological research during their school years to train qualified human resources (CNPq, 2006). These Brazilian programs are called Scientific Initiation (SI) and are offered by educational and research institutions that have qualified professionals on staff to work in the field of research, in addition to other requirements. Thus, SI programs are offered in various forms, benefiting students from high school to the undergraduate level. The outcomes of student experience in SI include the structuring of postgraduate programs, success in undergraduate research projects, the consolidation of research groups, and the promotion of activities to disseminate researchers' results involving both faculty and students (Noll et al., 2021). Given this, there is a latent responsibility, which invokes a sense of national pride and promotes skills to deal with complex situations and challenges, leading to qualified actions in the future (Melo et al., 2023).

While UR offers significant advantages to students, it is equally important to address the obstacles that hinder their participation and lead to low engagement rates (Melo et al., 2023). Barriers such as undervaluation of SI programs, excessive activities, and insufficient infrastructure and resources can limit the effectiveness and reach of these programs (Costa et al., 2024). However, overcoming these barriers can significantly broaden students' perceptions of science and future careers, enhancing their intelligence and maturity (Amaya et al., 2018). This underscores the need for higher education institutions to provide adequate resources, quality guidance, and recognition to improve student engagement in these programs (Melo et al., 2023). Moreover, participation in scientific research programs can greatly influence and direct students to continue their academic careers and can influence the construction of scientific identity (Ceyhan & Tillotson, 2020). By creating the conditions necessary to expand the number of undergraduate students engaged in scientific research, institutions can contribute significantly to the advancement of knowledge in various fields (Melo et al., 2023).

Given the scarcity of research in Latin American countries, especially in Brazil, our study aimed to fill this gap by evaluating the experiences of research students, their self-perceptions, and their scientific production as a result of their involvement in SI activities. We employed a quantitative survey approach to gather data. The findings of this investigation can significantly contribute to the understanding of the importance of UR programs for the development of the next generation of scientists and researchers.

Study Design

This study is part of an umbrella study named the "Panorama of Undergraduate Research in Brazil" (PUR-Bra study). The methodological design was based on quantitative analysis of curricula vitae, and an electronic survey was conducted on students enrolled in a Brazilian Midwest Institute. This research was approved by the Ethics Committee (Protocol CAAE No. 08499119.9.0000.0036, by consolidated opinion No. 3186828), and all participants consented to participate voluntarily, according to Brazilian ethics legislation.

The research instrument was validated to assess the organization, objectivity, clarity, ease of reading, and understanding of the content. The questions were analyzed using the Content Validity Index (CVI), which measures the proportion of evaluators who agree on specific aspects of the instrument (Alexandre & Coluci, 2011).

The target audience was students who were participating in an experience at UR during the 2018-2019 academic term. The sample was restricted to students who answered the survey questionnaire. The students were divided into two groups according to their research experience: students who were participating in a research program for the first time and experienced students at UR.

The data were analyzed using descriptive and inferential statistics, by the software Statistical Package for the Social Sciences (IBM™ SPSS™ Statistics), version 26 for Microsoft Windows™ (IBM Corp., Armonk, N.Y., USA). Absolute numbers and percentages were used for the descriptive analysis of the data. The Pearson's parametric chi-square test ($\alpha = 0.05$) was used to calculate the chi-square (χ^2) value (Henrique et al., 2022; Ugoni & Walker, 1995). To avoid statistical power loss, the last three answer options of some questions were grouped together and classified as "very good", "good", and "indiferente/ partially/ totally disagree" options (Melo et al., 2023).

The mean and standard deviation were used in the students' scientific production, and the normality of the data was assessed using the Kolmogorov–Smirnov test (Hazra & Gogtay, 2016). Given the non-normal distribution observed, we used a non-parametric test, the Mann–Whitney *U*-test, to assess whether there was a statistically significant difference ($\alpha = 0.05$) (Hazra & Gogtay, 2016; Leitão et al., 2021).

Results and Discussion

The sample included 213 students (115 female, 54.0%), 110 (51.6%) students who were novices in a research program, and 103 (48.4%) experienced students. The results showed that students who had participated in research activities more than once perceived the benefits of SI more positively ($p = 0.047$; see Table 1) and demonstrated a greater volume of academic production than those who were participating for the first time ($p < 0.001$; see Table 2).

Table 1: Students' perceptions of the benefits of SI.

Variables	**Total (*N* = 213) *n* (%)**	**Experience with SI** Novice (*N* = 110) *n* (%)	**Experience with SI** Experienced (*N* = 103) *n* (%)	***p*-value**
a) Is the SI important in undergraduate studies?				
Totally agree	187 (87.8)	96 (87.3)	91 (88.4)	
Partially agree	24 (11.3)	14 (12.7)	10 (9.7)	0.276
Indifferent, partially, or totally disagree	2 (0.9)	0 (0.0)	2 (1.9)	
b) Will your academic skit improve in the postgraduate stage due to this experience in SI?				
Totally agree	145 (68.1)	71 (64.5)	74 (71.8)	
Partially agree	62 (29.1)	33 (30.0)	29 (28.2)	**0.047 ***
Indifferent, partially, or totally disagree	6 (2.8)	6 (5.5)	0 (0.0)	
c) In the future, will you intend to apply to a postgraduate program?				
Yes	152 (71.3)	76 (69.1)	76 (73.8)	
No	11 (5.2)	7 (6.4)	4 (3.9)	0.635
Not sure	50 (23.5)	27 (24.5)	23 (22.3)	
d) Do you intend to continue in the SI program?				
Yes	131 (61.5)	65 (59.1)	66 (64.1)	
No	30 (14.1)	12 (10.9)	18 (17.5)	0.093
Not sure	52 (24.4)	33 (30.0)	19 (18.4)	
e) Could the SI activities help you get a good job in the future?				
Totally agree	126 (59.2)	62 (56.4)	64 (62.2)	
Partially agree	65 (30.5)	35 (31.8)	30 (29.1)	0.633
Indifferent, partially, or totally disagree	22 (10.3)	13 (11.8)	9 (8.7)	

Note: *N* represents the number of participants; *n* represents the number of responses for an alternative to the question. Mann–Whitney *U*-test ($\alpha = 0.05$): * statistically significant difference. The last three answer options of some questions were grouped together and classified as 'totally agree', 'partially agree', and 'indifferent/ partially/ totally disagree' to avoid statistical power loss.

Table 2: Academic production of the students.

Variables	**Experience with SI** Novice $M \pm SD$	**Experience with SI** Experienced $M \pm SD$	***p*-value**
Scientific articles	0.07 ± 0.35	1.18 ± 3.02	**<0.001 ***
Scientific articles in English	0.03 ± 0.16	0.52 ± 1.53	**<0.001 ***
Extended abstracts	0.90 ± 2.28	4.70 ± 5.54	**<0.001 ***
Abstracts	0.99 ± 2.09	4.75 ± 5.86	**<0.001 ***
All productions	**2.10 ± 4.02**	**11.38 ± 12.89**	

Note: *M* and *SD* represent the mean and standard deviation, respectively. Mann–Whitney *U*-test ($\alpha = 0.05$): * statistically significant value.

Both groups agreed that experience in SI will contribute to better academic performance in postgraduate programs (novices: 64.5%; experienced: 71.8%). Our findings align with existing evidence that such experiences foster gains in independence and intrinsic motivation to learn (Lopatto, 2007). The impact of UR experiences on students' competence in postgraduate studies is notably positive, with research capacity being a strong predictor of academic performance in postgraduate programs (Guo et al., 2021). Additionally, involvement in UR significantly increases the likelihood of students pursuing scientific fields and advancing to postgraduate school (Hernandez et al., 2018). Conversely, poorly managed UR experiences can pose challenges for students in their graduate studies (Dolan & Johnson, 2010), underscoring the importance of ensuring these experiences are rewarding to develop the necessary skills and competencies effectively (Wang et al., 2023).

Most participating students expressed their intention to continue their involvement in SI (novice: 59.1%; experienced: 64.1%), indicating the positive trajectory of Brazilian SI programs. These results are consistent with findings suggesting that students engaged in multiple research cycles had significantly higher scientific production, including articles and abstracts, than those participating only once, i.e., UR experiences contribute to cognitive and personal growth (Hunter et al., 2007). In addition, our findings corroborate with another study, showing that students' scientific productivity improves with more significant experience in UR (Zydney et al., 2002).

Furthermore, the students engaged in multiple research cycles demonstrate significantly higher scientific production, including articles and abstracts, compared to those with only a single cycle. Thus, an extended engagement in UR results in a deeper understanding of scientific research processes and developing essential skills for future scientists (Thiry et al., 2012).

Like any other study, ours has some limitations that are important to report. Firstly, the participants in our study belonged to a single Brazilian institution, which may have influenced the results. Therefore, it is suggested that future studies address a larger target audience and a broader context. Secondly, despite the researchers' efforts in this study's original design, some potentially relevant variables, such as leadership capacity, level of engagement, and sense of belonging, were only noticed after the data had been collected. Finally, we highlight that the new results obtained by replicating this research could generate insights that enable a better understanding of the evolution of public policies aimed at academic and scientific training in Brazil, allowing more effective decisions to improve them.

Conclusion

In conclusion, undergraduate students who participate in UR programs, as in Brazilian SI programs, contribute positively to academic production and training by providing personal and professional benefits and the opportunity to produce academic work that can help initiate academic careers. Based on the study's results, the information and knowledge gathered can contribute to developing institutional strategies and actions to increase support for Brazilian and UR programs in other countries.

Acknowledgments

We thank the *Instituto Federal de Educação, Ciência e Tecnologia Goiano* for its financial aid and are grateful for the Institutional Qualification Program (*Programa Institucional de Qualificação - PIQ*) grant. Additionally, we express our gratitude to the Research Group on the Health of the Child and the Adolescent (*Grupo de Pesquisa sobre Saúde da Criança e do Adolescente - GPSaCA* - https://www.gpsaca.com.br/) for its support.

References

Alexandre, N. M. C., & Coluci, M. Z. O. (2011). Content validity in the processes of construction and adaptation of measurement instruments. Public Science & Health, 16(7), 3061–3068. https://doi.org/10.1590/S1413-81232011000800006

Amaya, L. R., Betancourt, T., Collins, K. H., Hinojosa, O., & Corona, C. (2018). Undergraduate research experiences: mentoring, awareness, and perceptions—a case study at a Hispanic-serving institution. International Journal of STEM Education, 5(1), 9. https://doi.org/10.1186/s40594-018-0105-8

Ceyhan, G. D., & Tillotson, J. W. (2020). Early year undergraduate researchers' reflections on the values and perceived costs of their research experience. International Journal of STEM Education, 7(1), 1–19. https://doi.org/10.1186/s40594-020-00248-x

Chen, J. (2021). Analysis on the driving effect of scientific and technological innovation on the coordinated development of regional economy. BCP Business & Management, 15, 45–49. https://doi.org/10.54691/bcpbm.v15i.210

CNPq. (2006). Normative Resolution no 17/2006: quota scholarships in the country. http://memoria2.cnpq.br/view/-/journal_content/56_INSTANCE_0oED/10157/100352? COMPANY_ID=10132

Costa, W. P., Fernandes, M. S. V., Memon, A. R., Noll, P. R. E. S., Sousa, M. M., & Noll, M. (2024). Factors influencing the work of researchers in Scientific Initiation: a systematic review protocol. PLoS One, 19(1), e0297186. https://doi.org/10.1371/journal.pone.0297186

Daniels, H., Grineski, S. E., Collins, T. W., Morales, D. X., Morera, O., & Echegoyen, L. (2016). Factors influencing student gains from undergraduate research experiences at a hispanic-serving institution. CBE—Life Sciences Education, 15(3), ar30. https://doi.org/10.1187/cbe.15-07-0163

Dolan, E. L., & Johnson, D. (2010). The undergraduate–postgraduate–faculty triad: unique functions and tensions associated with undergraduate research experiences at research universities. CBE—Life Sciences Education, 9(4), 543–553. https://doi.org/10.1187/cbe.10-03-0052

Guo, J., Chen, Z., & Zheng, B. (2021). Postgraduate competence and academic research performance: the mediating role of psychological capital. Sustainability, 13(11), 6469. https://doi.org/10.3390/su13116469

Hazra, A., & Gogtay, N. (2016). Biostatistics series module 3: comparing groups: numerical variables. Indian Journal of Dermatology, 61(3), 251–260. https://doi.org/10.4103/0019-5154.182416

Hernandez, P. R., Woodcock, A., Estrada, M., & Schultz, P. W. (2018). Undergraduate research experiences broaden diversity in the scientific workforce. BioScience, 68(3), 204–211. https://doi.org/10.1093/biosci/bix163

Henrique, N. C. P., Hilário, J. S. M., Louzada, F. M., Scorzafave, L. G. D. S., Santos, D. D., & Mello, D. F. (2022). Child sleep habits and maternal perception during the child's first year of life. Journal of Human Growth and Development, 32(3), 321–330. https://doi.org/10.36311/jhgd.v32.13095

Leitão, F. N. C., Ferreira, C. R. T., Abreu, K. L., Deus, M. B. B., Macedo Junior, H., & Morais, M. J. de D. (2021). Effects of the social isolation generated by COVID-19 on the quality of life of the population in two Brazilian cities. Journal of Human Growth and Development, 31(3), 405–413. https://doi.org/10.36311/jhgd.v31.12609

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. CBE—Life Sciences Education, 6(4), 297–306. https://doi.org/10.1187/cbe.07-06-0039

Lopatto, D. (2010). Undergraduate research as a high-impact student experience. Peer Review, 12(2), 27–31. https://eloncdn.blob.core.windows.net/eu3/sites/126/2020/10/Lopatto-2010.pdf

Mahatmya, D., Morrison, J., Jones, R. M., Garner, P. W., Davis, S. N., Manske, J., Berner, N., Johnson, A., & Ditty, J. (2017). Pathways to undergraduate research experiences: a multi-institutional study. Innovative Higher Education, 42(5), 491–504. https://doi.org/10.1007/s10755-017-9401-3

Mantai, L., Swain, C., Bearman, M., & Brew, A. (2023). Assessment of student learning in undergraduate research engagement. Higher Education Research & Development, 1–15. https://doi.org/10.1080/07294360.2023.2218808

Melo, A. F., Costa, W. P., Rodrigues, R. R., Nunes, L. A. C. B., Noll, P. R. E. S., & Noll, M. (2023). Panorama of undergraduate research in Brazil: profile, scientific production, and perceptions. Publications, 11(2), 30. https://doi.org/10.3390/publications11020030

Mieg, H. A., Ambos, E., Brew, A., Galli, D., & Lehmann, J. (2022). The Cambridge handbook of undergraduate research. Cambridge University Press. https://doi.org/10.1017/9781108869508

Noll, M., Melo, A. F., Araújo, T. G., & Soares, F. A. L. (2021). Profile of scientific initiation students in Brazilian Federal Institutes: research areas, gender, and scholarship type by region. Research, Society and Development, 10(11), e511101119936. https://doi.org/10.33448/rsd-v10i11.19936

Thiry, H., Weston, T. J., Laursen, S. L., & Hunter, A.-B. (2012). The benefits of multi-year research experiences: differences in novice and experienced students' reported gains from undergraduate research. CBE—Life Sciences Education, 11(3), 260–272. https://doi.org/10.1187/cbe.11-11-0098

Ugoni, A., & Walker, B. F. (1995). The chi square test: an introduction. COMSIG Review, 4(3), 61–64. http://www.ncbi.nlm.nih.gov/pubmed/17989754

Wang, F., King, R. B., Zeng, L. M., Zhu, Y., & Leung, S. O. (2023). The research experience of postgraduate students: a mixed-methods study. Studies in Higher Education, 48(4), 616–629. https://doi.org/10.1080/03075079.2022.2155344

Zheng, Y. (2023). University teachers' scientific research innovation incentive based on the three-party evolutionary game of the state, the colleges, and scientific researchers. Frontiers in Psychology, 13, 1–12. https://doi.org/10.3389/fpsyg.2022.973333

Zydney, A. L., Bennett, J. S., Shahid, A., & Bauer, K. W. (2002). Impact of undergraduate research experience in engineering. Journal of Engineering Education, 91(2), 151–157. https://doi.org/10.1002/j.2168-9830.2002.tb00687.x

Contact email: woskapc@gmail.com