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Intersectionality in STEM Education: Review and Categorization of Programs Focused on Indigenous Students

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Abstract

United Nations Sustainable Development Goal 4 (SDG 4) focuses on education and seeks to promote inclusive, equitable, and quality education, providing opportunities for all. In this context, it seeks to promote intersectionality (gender and ethnicity) as a fundamental factor in education, and in science, technology, engineering, and mathematics (STEM) careers in particular. Similarly, it aims to support programs that include the gender gap in their studies to mitigate the lack of Indigenous women and/or students from native peoples in STEM careers. The objective of this work was to carry out a categorization of programs aimed at Indigenous students in their processes of access, retention, and follow-up in STEM careers, with the purpose of making visible the variety of approaches and programs that have been created in different regions of the world. A systematic review was conducted to analyze the programs, and the classical content analysis method of scientific production was employed. The main results of the analysis are classified into three main categories: the characteristics of the studies, the programs, and their results. In relation to the study's contribution, the aim is to generate knowledge and understanding of the programs identified to promote the inclusion of this underrepresented population in STEM education.

Keywords: *Higher education, intersectionality, indigenous students, programs, STEM, systematic review*

Introduction

In 2015, the United Nations approved 17 Sustainable Development Goals (SDGs) as part of the 2030 Agenda for Sustainable Development, with the aim of building more sustainable knowledge-based societies. SDG 4 focuses on education and seeks to ensure inclusive, equitable, and quality education, promoting opportunities for all (UNESCO, 2019).

However, achieving this goal is threatened if science education remains inaccessible to some groups (Sánchez et al., 2018), increasing the disparity between Indigenous and non-Indigenous

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students in science, technology, engineering, and mathematics (STEM) careers (Jin, 2021; Kim, 2017; Miller & Armour, 2021). This imbalance is evident in the limited access of the Indigenous population to higher education. To overcome this gap, it is essential to implement programs that respect the cultural identity of students, aligning science programs to the traditional knowledge they acquire from their peoples and ancestors with Western knowledge (Sánchez et al., 2018). In response to this necessity, recent programs have been developed that engage Indigenous children and students in their STEM education, aligning them with their cultures and traditional knowledge (Lowe et al., 2021; Mack et al., 2012; Miller et al., 2021). Likewise, other studies mention the influence of teacher roles, educational programs, and policies on Indigenous students' experiences and academic achievement (Brown, 2017; Gillan et al., 2017; Jin, 2021; Miller et al., 2021; Vass et al., 2019). They recommend deepening 'evidence-based research in program development, implementation, and evaluation and ensuring Indigenous voices in program development' (Vass et al., 2019, p. 77).

Based on this recommendation, this paper aims to emphasize the significance of intersectionality, particularly regarding gender and ethnicity, in education (SDG 4) and STEM careers, as highlighted by García-Holgado et al. (2020). Moreover, we seek to showcase programs that address the gender gap, as identified by Verdugo-Castro (2022), in their efforts to reduce the underrepresentation of Indigenous women and students from native peoples in STEM disciplines. These individuals constantly face multiple challenges in developing STEM careers, including ethnic and cultural discrimination, language barriers, gender violence, economic limitations, family pressures, persistent stereotypes. This visibility also contributes to fostering the preservation of Indigenous identity as these women strive to access different levels of education (FPCI, 2018).

To provide evidence of these actions, the aim of this paper is to categorize programs aimed at Indigenous students with a focus on their access, retention, and follow-up in STEM careers. The main research question guiding this review is: 'What types of programs targeting Indigenous students have been created to mitigate the gap in their access to higher education in STEM?' The purpose is to make visible the variety of approaches and programs that have been developed in different countries to promote the participation of Indigenous students in these disciplines, rescuing the knowledge transferred and the good practices implemented.

This research seeks to contribute to the knowledge and understanding of programs designed for Indigenous students in STEM careers, offering insights into the challenges and effective practices used to enhance the inclusion of this underrepresented population in STEM education. Furthermore, it can serve as a valuable reference for educators, researchers, policy makers, and organizations interested in initiating similar initiatives.

The rest of this paper is organized as follows. The second section presents a theoretical framework, while the third section shows the methodology for collecting and analyzing the information. The fourth section presents the main results, followed by discussions in the fifth section. Finally, the last section presents the conclusions and limitations of the research.

Theoretical Framework

Data indicate that women and ethnic and racial minorities groups continue to be underrepresented in the STEM field (Stevens et al., 2016), and many factors hinder the educational success of Indigenous students (Gillan et al., 2017). To address these challenges, it is crucial to enhance the learning experiences of Indigenous students (Vass et al., 2019) and provide them with quality and inclusive access to higher education. For this purpose, it is essential to involve native communities in decision-making processes to support the development of initiatives that benefit the education of their youth and their access to STEM careers (Gillan et al., 2017).

In an attempt to close this gap in access to higher education in STEM, some countries, such as the United States, Australia, New Zealand, and Chile, have directed their attention to young people from Indigenous backgrounds by creating different initiatives. However, significant disparities still persist between Indigenous and non-Indigenous students in terms of both entry into higher education and successful completion (Kim, 2017; Liu et al., 2023).

The theory of intersectionality, developed by Crenshaw (1991), provides a useful conceptual framework for addressing the identities and social contexts that influence Indigenous students' access and success in STEM. This theory highlights the interactions of gender, ethnicity, race, social class, and other categories of difference, making it possible to identify experiences of disadvantage and explore how they are intertwined with power and privilege (Ávila et al., 2021). Intersectionality theory makes visible the multiple discriminations that some people suffer because of certain conditions (Collins, 2007). In summary, intersectionality addresses the idea that the elements that make up identity do not exist in isolation nor are they mutually exclusive; rather, they interact with each other to construct a unique and complex identity (Collins, 2007; López et al., 2022).

In the field of higher education, intersectionality presents itself as a useful tool for studying how experiences of marginalization, stemming from various dimensions of identity, are intertwined with privilege or oppression. This is especially relevant in STEM areas, where women and minority individuals have been historically underrepresented (Ávila et al., 2021; Shields, 2008; Winker et al., 2011).

Therefore, it is necessary to address the inclusion of new forms of learning in higher education taking into account these multiple identities of students and intertwining them with the cultures, traditions, and worldviews of their peoples. In others words, culturally relevant and responsive education is necessary to integrate students, schools, and their communities in a safe learning environment where education is more equitable and cultural identity is respected (Charles Sturt University, 2023; Rigney, 2017). Integrating Indigenous knowledge, stories, and values into programs can ensure that all students can understand and respect the heritage of others as well as their own, achieving culturally appropriate and culturally relevant equitable access in an inclusive and diverse environment in higher education (Barnhardt et al., 2000; LaFrance et al., 2009; Velez et al., 2022).

In this context, the present study aims to contribute by identifying programs specifically designed for indigenous students, which can serve as inspiration in the development of future programs aimed at this population. The study seeks to answer the question "What types of programs targeting indigenous students have been created to mitigate the gap in their access to higher education in STEM?" To address this question, the review identified programs and outcomes reported in the published literature, leading to the formulation of two supporting research questions: (1) What are the characteristics of higher education programs that support Indigenous students; and (2) What outcomes have been reported for these programs?

Method

Data and sources of data

The data used for the study was extracted from two main data sources, Scopus and Web of Science (WoS) following specific guidelines described below.

Design and Search Process of the Systematic Review

This review followed the internationally recognized PRISMA guidelines, which describe the criteria for reporting systematic reviews (García-Peñalvo, 2022; Page et al., 2021). It is focused on two main databases, Scopus and Web of Science (WoS), using three term sets for the search query. The first term set focused on studies on Indigenous students (i.e. 'Indigenous' OR 'Native' OR 'ethnicity' OR 'First Nations'), the second term set is about higher education, and the last set focused on STEM disciplines. These sets of search terms were combined using the AND operator. Other limiters were also applied in the initial search, including published between 2015 and April 2023. After removing duplicates, the initial search returned a total of 529 records.

Study Selection and Eligibility

For the selection and evaluation process of the 529 records, the titles and abstracts were read to identify relevant research studies, leaving a total of 101 records, to which the following inclusion criteria were applied: (1) articles proposing programs or studies that focus on Indigenous students at the higher education level; (2) peer-reviewed scientific articles, conferences, books, and book chapters; (3) written in Spanish or English; and (4) full text version available. After the application of the criteria, 51 records remained, the texts of which were reviewed in full, focusing on their eligibility for final inclusion in the review. After completing the full-text scan, 24 articles remained for inclusion in this review. Figure 1 details the search and selection process using the PRISMA flowchart.

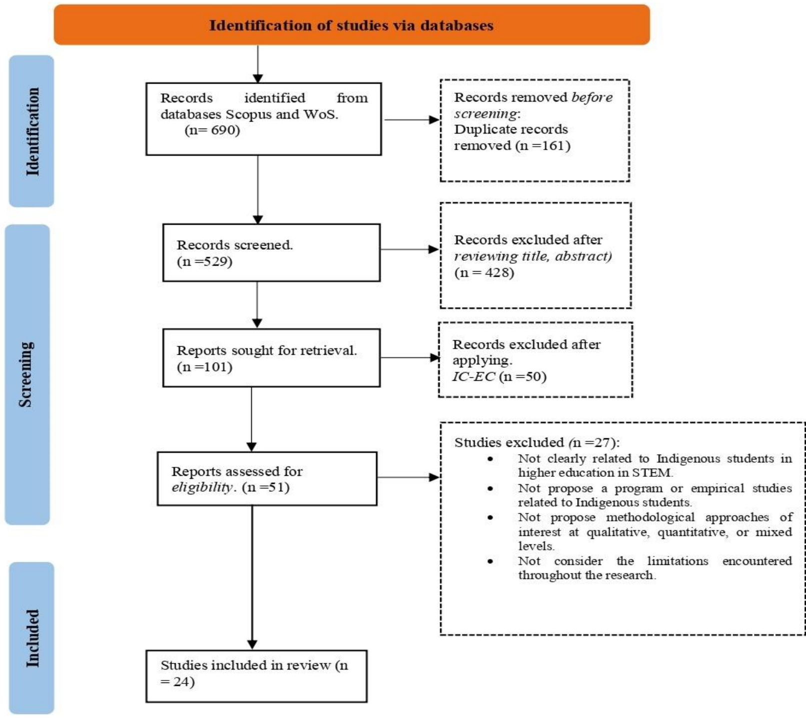

Figure 1. *PRISMA flow diagram*

To ensure validity, a series of measures were applied to preserve the objectivity of the results, such as reviewing previous SLRs to confirm the need to carry out this review and following a systematized and documented way of complying with the inclusion and quality criteria in order to mitigate possible biases. Although a protocol has been followed, this does not guarantee that all the publications related to the subject are included; to weigh this risk, a search was carried out in two research databases, Web of Science and Scopus. The reproducibility of the study is considered, and the data extraction process is described and documented, with spreadsheets and source files available in a repository at https://doi.org/10.5281/zenodo.10452236.

Data Analysis

Classical content analysis was used for data analysis, with the intention of delving into the significant contents of programs focused on Indigenous students, answering the research question: What types of programs aimed at Indigenous students have been created to mitigate the gap in their access to higher education in STEM?

Classical content analysis of scientific output helps to construct a codebook that describes the main coding categories of interest by extracting the exact wording (Saldaña, 2013).

For the development of the codebook, an inductive analysis was followed by coding potentially significant information such as words, sentences, and paragraphs (Rodríguez, 2021). Additionally, during the process, four fundamental steps were followed, which included data reduction, data unfolding, drawing conclusions, and verification (Huberman et al., 1994).

Finally, categories and subcategories were created to allow the classification and analysis of the information contained in the 24 articles resulting from the systematic review. The studies identified were rigorously coded for analysis, leading to the development of a codebook describing the main categories of interest (see Table 1).

Table 1

Coding of articles (Source: own elaboration)

Category	Subcategory	Coding examples
Characteristics of the studies	Publication outlet	Journal of College Student Retention: Research, Theory and Practice, Journal of Chemical Education, International Journal of Innovation in Science and Mathematics Education, etc.
	Year of publication	2015–2023
	Countries	United States, Canada, Australia, New Zealand, Chile
	Methodology	Qualitative, quantitative, mixed method
	Original population	Native Hawaiians, Maori, Native Americans, Mapuche, First Nations or Amerindians in Canada, Aboriginal and Pacific Islanders
Characteristics of the programs	Type of programs identified	Retention programs, mentoring, summer camps and math courses
	Program context	Formal and informal context
	Responsible for program implementation	Universities, researchers, Indigenous knowledge holders, others
	Time of program	Two weeks, one semester, one academic year, entire university term, not mentioned
Results of the studies	Results reported	Results reported: positive, negative, none
		Approach to science activities
		Choice, retention, and follow-up in STEM careers
		Interest and attitudes towards science
		Inclusion of Indigenous knowledge and culture

		Combination of science and Indigenous knowledge
		Cultural barriers, spiritual, family engagement, community, first generations

To analyze the coding results and where appropriate, we used counting to aggregate the data, which allowed us to identify trends the data (Huberman et al., 1994). These data provided a general description of the programs included in the final sample.

Findings

The main results of the analysis can be grouped into three general categories: the characteristics of the studies, the programs, and their results. The first category refers to the characteristics of the studies uncovered in the systematic review. The second category describes the types of programs identified to answer the main question of this study. Finally, the third category encompasses the results of the studies, summarizing the key topics addressed in the articles (Table 1).

Characteristics of the Studies

Of the 24 studies identified in the systematic review, 19 were published in journals with a primary focus on subjects related to Indigenous people or diversity in higher education (e.g. Australian Journal of Indigenous Education), science and mathematics (e.g. International Journal of Innovation in Science and Mathematics Education), chemistry (e.g. Australian Journal of Chemistry, Journal of Chemical Education), technology (e.g. Journal of Science Education and Technology), education (e.g. Journal of Latinos and Education, Science Education, Frontiers in Education), and retention of students in higher education (e.g. Journal of College Student Retention: Research, Theory and Practice).

Additionally, five studies were located in conference proceedings, with four of them being from ASEE (American Society for Engineering Education) and one from Springer Proceedings in Mathematics and Statistics (Figure 2).

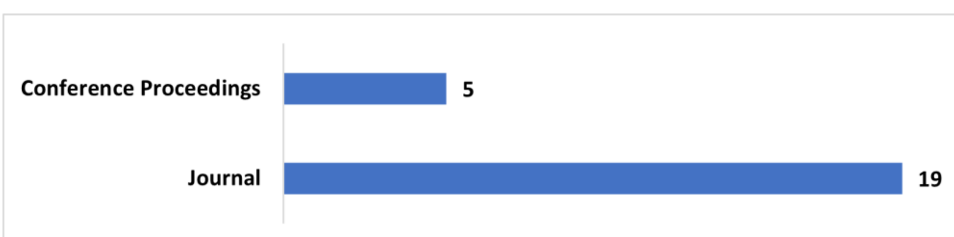

Figure 2. *Publication outlet (Source: own elaboration)*

In terms of publication years, 11 studies (45.83%) were identified in the first five years (2015 to 2019), while 13 studies (54.16%) were found in the period from 2020 to April 2023 (Figure 3).

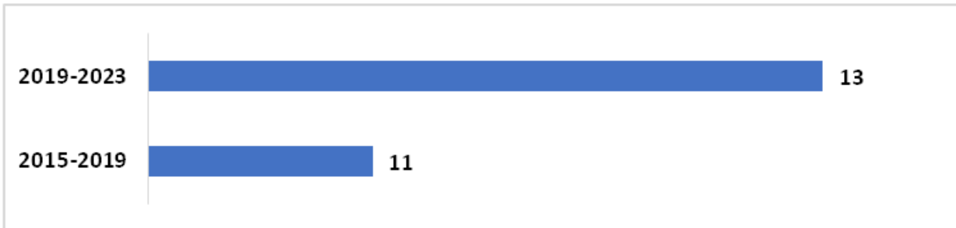

Figure 3. *Year of publication (Source: own elaboration)*

Regarding distribution by country, the United States had the highest representation with 15 studies, followed by New Zealand, and Australia each with 3 studies, Chile with 2 studies, and Canada with 1 study (Figure 4).

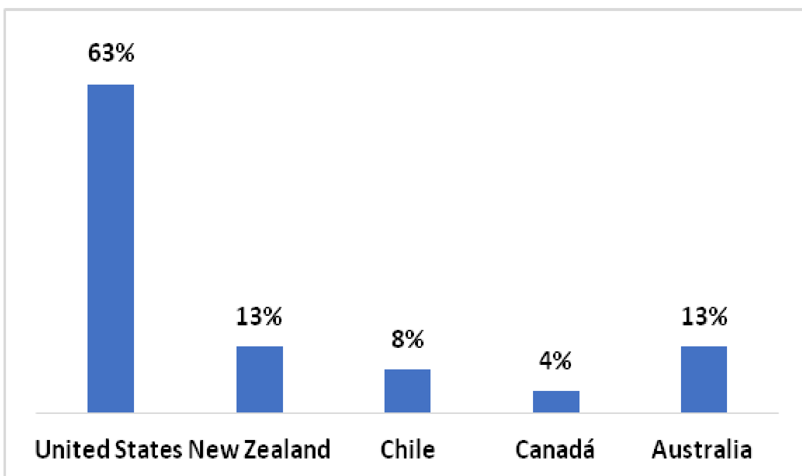

Figure 4. *Percentage of studies by country (Source: own elaboration)*

Regarding the methodology used, six studies employed qualitative methodology, incorporating focus groups and questionnaires. Three of them utilized case study methodology, while the remaining 15 studies, primarily focusing on programs, employed various methods and tools, including questionnaires, in-depth interviews, and quantitative analysis (Figure 5).

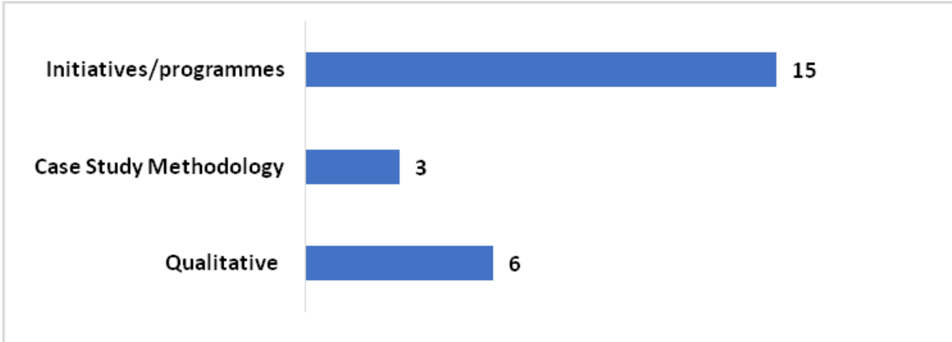

Figure 5. *Methodology (Source: own elaboration)*

Finally, the studies identified various native populations, including Native Hawaiians, Pacific Islander students, First Nations or Amerindian students in Canada, Native Americans, Mapuche, Maori, Aboriginal and Torres Strait Islanders, as well as minority groups such as women and Latinos. It is important to mention that, as discussed in Bonny, (2018), the term indigenous encompasses pre-colonial inhabitants geographically differentiated from territories around the world. In Canada, indigenous peoples include members of various First Nations, Inuit, and Métis communities. In the United States, Native Americans and Alaska Natives are officially recognized as indigenous groups. Similarly, Aboriginal and Torres Strait Islander peoples are the indigenous peoples of Australia, and Māori are the indigenous peoples of Aotearoa (New Zealand), while Pasifika communities are comprised of migrants from various lands in the Pacific region (Enari & Haua, 2021). In Chile, the Mapuche are the most numerous (IWGIA, 2023).

Characteristics of the Programs

Various types of programs were identified, developed in both formal and informal settings and in both contexts. These programs can be categorized as retention and follow-up programs for Indigenous students in higher education, mentoring programs, summer camps, or mathematics courses. Of the 24 studies identified, 12 (50%) are programs developed in the formal context, primarily within universities and laboratories during academic hours. Only one program (4.1%) was implemented in an informal context (outside the classroom). In 5 (20.83%) of the programs, activities occurred in both formal and informal settings. The remaining 6 (25%) empirical studies were mostly carried out in the formal context, which refers to activities that take place within the regulated educational system, characterized by highly structured organization and adherence to stable rules (Soto et al., 2023).

Programs in a Formal Context

Several formal programs aimed at retaining and providing follow-up support to Indigenous students were identified within university settings. These programs typically involve the participation of science researchers, native professors, and university staff. For instance, at the University of Virginia (USA), a hybrid program was identified. This program included a week-long in-person orientation at the university, a year-long academic follow-up, and a six-week summer course in chemistry and mathematics, developed between 2014 and 2019. Over 200 students participated in this program, with 65% of them being female (Gibson et al., 2021).

The specific work in the STEM area, is mainly oriented to this individual accompaniment in supporting students in bridge programs, mentoring, workshops and research experiences by mentors willing to support students, not only in the laboratories but also complementing their knowledge and skills according to the needs of the students. Furthermore, in this accompaniment it was found that students who care about their communities are able to appreciate the transnational impacts of their STEM knowledge and skills to help solve critical problems in their environments, likewise highlighting the effectiveness of the service-learning program approach that benefits students in their academic performance and leadership skills development (Gibson et al., 2021).

Similarly, the University of Drexel (USA) implemented the 'Raising Interest in STEM Education' (RISE@Drexel) program, designed to engage Indigenous students and underrepresented minority groups in STEM careers. The program selected six students out of a total of 20 to join research groups related to their interests. The program lasted for ten weeks, during which students demonstrated proficiency in basic research methods and interest in STEM education and careers (Christe et al., 2015).

The Raising Interest in STEM Education' (RISE@Drexel) program focus primarily on this hypothesis that science and engineering learning is best developed in a peer microenvironment rather than independently. Therefore, this program develops and encourages active learning through a pedagogy focused on "open-ended" problem-solving experiences, where external parties such as librarians help students understand and learn to search for themselves the resources they need for the realization of their projects, thus structuring a program with an engaging, hands-on, and supportive learning environment aimed at UMS (Christe et al., 2015).

In a similar vein, the 'Wabanaki Youth in Science' (WaYS) program, implemented at the University of Maine (USA), aimed to connect Indigenous students with their communities and culture. Additionally, it encouraged enrolment in science careers through life science training (Carr et al., 2017).

The development of this program was achieved by introducing multiple ways of approaching teaching and learning in STEM, using a multi-faceted approach (i.e., camps, community outreach, and internships with cultural resource and natural resource mentors) to motivate Native youth to pursue science fields. The program with a longitudinal and multi-faceted approach is really inspiring and useful that shows how through these summer camps, traditional ecological knowledge programs at tribal centers for teens, internships with cultural resource mentors, has succeeded in retaining Native youth in the sciences (Carr et al., 2017).

In New Zealand, an initiative called 'Readiness, Recruitment, Retention, Role Modelling, and Research' (the 5 Rs) was created during 2003–2010 at the University of New Zealand, which helped increase the pass rate among Maori students at the University. In 2015, more than 567 Maori and Pacifica students improved their academic performance, and retention was 100% (Leydens et al., 2017).

The implementation of this STEM program was based on initial efforts to take advantage of indigenous forms of knowledge, promoting contextual listening, i.e., understanding social structural conditions, thus allowing to promote inclusion and respect each of the groups of students involved (Leydens et al., 2017).

In Chile, the 'RÜPÜ' program, developed at the Universidad de la Frontera and Universidad Austral de Chile, focuses on promoting academic guidance and socio-cultural aspects to enhance the integration of Indigenous students into university life (Silva et al., 2020a). Other key aspects of these programs include mentoring and hands-on activities designed to integrate and retain native students in STEM careers. For example, the 'Wabanaki Youth in Science' (WaYS) program provides students with the opportunity to work with environmental leaders and tribal elders on tribal environmental issues, emphasizing the importance of science within their communities (Carr et al., 2017). A similar approach is taken in the 'Raising Interest in STEM Education' (RISE@Drexel) program, where students are connected with a PhD student who serves as a role model and guide in their technical work, fostering integration into the scientific community (Christe et al., 2015).

Other significant venues for promoting mentoring and highlighting the role of researchers or professors as mentors include internship programs. For instance, one such program is conducted at tribal colleges and universities (TCU), specifically at the Chief Dull Knife College (CDKC). Additionally, a second 'REU' program was offered by the University of Montana (USA), spanning three years from 2015 to 2017 (Ward et al., 2022). Another notable initiative is the SEEDS Peer Mentoring program at the University of Maryland, also in the USA. This program facilitates mentoring relationships between new engineering students and upper-level students (Smith et al., 2017). A unique mentoring approach involved pairs of native Hawaiian students and native teacher mentors. These mentors encouraged the development of research skills and critical thinking among students, promoting self-directed learning and motivating them to carry out projects that contribute to their communities, thereby preserving and perpetuating their culture. This project extended over an 11-month period, commencing in March 2018, and was conducted at a public university in Hawaii (Zorec, 2022).

Programs in an Informal Context

Informal programs, such as summer camps, can be an effective method for showcasing the potential of STEM. For instance, a 'summer bridge program' was an initiative developed through collaboration between a community college and a research university in Hawaii. The program spanned one week each year for three years (2013 to 2015) and involved the participation of 64 students. Approximately two-thirds of the students belonged to underrepresented groups, while one-third were native Hawaiian students. Since the implementation of the summer course, four native Hawaiians have enrolled in geoscience majors at the University of Hawai'i at Mānoa (Bruno et al., 2016). This program emphasizes the role of mentoring, where alumni students from the University of Hawai'i at Mānoa's native program rejoin as mentors, acting as liaisons and helping to solidify students' decisions to pursue geoscience careers (Bruno et al., 2016).

The iSTEM program offered informal science education experiences primarily through field trips covering modular topics such as solar energy, optics, flight and motion, GPS, and astronomy. Additionally, 20-minute STEM flash activities were conducted during students' lunch periods at the school once a week, providing them with the opportunity to interact with their mentors.

Moreover, non-STEM-related activities were scheduled every two weeks, allowing mentors and students to enhance their connection by choosing activities related to their interests and hobbies, whether or not they were STEM-related. Over the three years of the iSTEM program, a total of 78 students participated, with 12 successfully completing all three years, 31 students participating for two years, and 35 for one year (Stevens et al., 2016). The program involved three types of mentors: Native American community members, college students, and STEM professionals. Student apprentices and mentors engaged in interactive STEM activities during lunch breaks and attended approximately six field trips per year. In total, 26 mentors were Native Easter Yanki, of which 6 were STEM professionals and 13 were college students (Stevens et al., 2016).

Another similar program is the one developed at Utah State University in the United States, which designed a summer mentoring program in an online format aimed at native students. The objective is to promote the collaboration of mentors and mentees, providing them with knowledge and research skills, in addition to promoting their access and continuation in STEM disciplines (Cannon et al., 2021).

Finally, it is important to mention that workshops related to science subjects are essential to strengthen acquired knowledge. At the University of Sydney in Australia, during the month of September 2017, a mathematics workshop was held as part of a week-long intensive program aimed at Indigenous students, organized by the faculty of engineering and information technology. Fourteen out of seventeen invited students attended. The multifaceted nature of the workshop provided an excellent opportunity to connect various aspects of the three worlds of mathematics, science, and engineering, as well as the life experiences of the students (Phillips & Ken, 2020).

The philosophy for conducting the mathematics workshops successfully was to learn about the student's background, past experiences, and culture, and to overcome past fears that may have arisen because standard teaching has failed them, thus helping to create a supportive and cooperative environment, be receptive to others' cultural perspectives, learn from them, and adapt to them. Use feedback to allow students to express their opinions throughout the teaching and development process in order to adapt, modify, and improve the quality of teaching (Phillips & Ken, 2020).

Programs in Both Contexts (Formal and Informal)

Some of the programs are complementary—that is, they are carried out in both formal and informal contexts, and some of them promote the connection between Western scientific research and Indigenous knowledge and culture. An example is the intervention program that is delivered from the first year at the University of Maryland in the United States, which includes a summer bridge program, a mentoring program, and specific live learning communities in engineering. The program is called 'SEEDS' and is composed of the Flexus program, which targets women in engineering at the University of Maryland, and the Virtus program, which targets male engineering students. Both programs focus on promoting community and support among first- and second-year engineering students through academic, social, and professional support services. There is also the SEEDS peer mentoring program, a first-year summer experience (FYSE) program, which is a three-week residential mentoring program focused on developing and strengthening engineering problem-solving skills, with special emphasis on precalculus and calculus. Between 2010 and 2015, 1,707 students participated in one or more SEEDS programs (Smith et al., 2017).

The AISES program aims to increase the number of American Indians and Alaska Natives in STEM education and careers. The program includes a monthly webinar in which students learn how to write a resume, balance work and personal lives, and integrate American Indian culture into their studies, work, lives, and research (Aspray, 2016). Along the same lines, at the University of Saskatchewan (Canada), a science ambassador program (SAP) was implemented, where science ambassadors are undergraduate graduate students and university professionals who go into communities to conduct science outreach activities for an average of four to six weeks with the aim of encouraging students to explore the possibilities of continuing their education and careers in STEM (Bonny, 2018).

In the development of this program, support for relational learning and flexible programming adapted to the specific teaching and learning needs of the communities, as opposed to fixed lesson plans, are emphasized. It also highlights the importance of taking into account the participants' life histories in order to adapt the activities and projects.

There are also educational programs that integrate Indigenous culture and identity along with academic rigor, such as the program developed in 2014 by the Commonwealth Scientific and Industrial Research Organization (CSIRO). Bachelor of Science (extended) is a supported pathway program offered by the University of Melbourne, a summer school program and an Indigenous mathematics education program (Trimmer et al., 2017). Finally, since 2004, the National

Indigenous Science Education Program (NISEP), based at Macquarie University in Sydney, has used the best ethical and inclusive strategies to engage with Aboriginal Australian and Torres Strait Islander school children and their communities (Barnes et al., 2022).

Reported Outcomes

The 24 studies included in this analysis reported positive results (Appendix A) regarding the influence that the programs have had on the retention of Indigenous students in STEM careers. The review of these results identified six categories in three groups, which are detailed in Appendix A. The first three categories (group I)—approach to science activities; choice, retention, and follow-up in STEM careers; and interest and attitudes towards science—were science- and/or STEM-related outcomes. The next two categories concerned connections and complementary links between science and Indigenous knowledge and cultures (group II). Finally, group III included internal and external factors. The six categories are not mutually exclusive (Table 2).

Table 2

Results of programs (Source: own elaboration)

Results		Explanation
I: Science/STEM	Outreach to science activities	Internships in research centers and companies, integration of summer courses, maths workshops, and mentorships for the development of scientific knowledge and research skills.
	Choice, retention, and follow-up in STEM careers	Initiatives that promote STEM careers, including access, retention, follow-up, and completion.
	Interest and attitude towards science	Development of interest and attitude towards science or STEM subjects, improving willingness to continue in STEM careers, and reaffirming confidence in learning science.
II: Complementarity of sciences and Indigenous knowledge	Inclusion of indigenous knowledge and culture	Understanding of Indigenous knowledge to boost pride in Indigenous cultures, traditions, and knowledge.
	Combination of Western science and Indigenous knowledge	Awareness and appreciation of the connection between Western scientific knowledge and Indigenous knowledge.
III: Internal and external factors	Cultural, spiritual barriers, family commitment, community, first generations	Internal and external factors that influence Indigenous students when choosing a STEM career.

Of the 24 studies included in this analysis, 10 (41. 6%) reported results related to science activities including choice, retention, and follow-up in STEM careers, as well as students' interests and attitudes towards science/STEM. Additionally, 8 (33%) studies emphasized the importance of knowledge complementarity, awareness, and appreciation of the connection between scientific knowledge and its contribution to Indigenous communities. Furthermore, 6 (25%) studies focused on discussing the primary internal and external factors affecting Indigenous students in higher education in STEM careers.

Initiatives to Support STEM Learning for Indigenous Students

Most of the work included in this analysis focused on supporting American Indian students in retaining and continuing in STEM fields. The emphasis is on bringing science activities together to foster conceptual learning of science and its application in the field, enabling students to gain hands-on skills and authentic research experiences to remain in these careers. For instance, the AISES program concentrates on providing American Indian students with skills and field experience, specifically in the fields of biology, computer science, chemistry, engineering, mathematics, geology, and astronomy (Aspray, 2016).

On the other hand, the Anthropological Water Heritage Project helped Native youth develop their research skills by teaching them ethnographic methods, providing knowledge about water resources and the basics of geographic information systems. This situation allowed for an expansion of their vocabulary in this field (Cannon et al., 2021) in addition to fostering a greater awareness of the contribution towards their Indigenous communities (Ward et al., 2022).

Moreover, science and engineering learning is most effective when combined with the challenge of independent research in a specific collaborative 'microenvironment', such as a research laboratory, where students can work with researchers serving as role models in a collaborative environment (Christe et al., 2015; Zorec, 2022). This can help increase interest in STEM careers. Additionally, combining various programs, such as summer camps, online courses, and maths or chemistry workshops, are key initiatives that help students become familiar with academic subjects and ease their transition to college (Gibson et al., 2021; Phillips et al., 2020). Moreover, they facilitate cultural inclusion, retention, and support through learning communities (Smith et al., 2017), thereby increasing enrolment in college in a more inclusive and equitable way (Leydens et al., 2017; Silva et al., 2020a; Trimmer et al., 2017).

Furthermore, there are initiatives in informal spaces, such as field trips and summer camps, that help strengthen and create a different environment for young people to experiment and learn about topics such as solar energy, optics, GPS, astronomy, mapping and GIS, earth and soils, watersheds, and ecology (Stevens et al., 2016).

Complementarity of Indigenous Education and the Sciences

The complementarity of Indigenous knowledge and Western scientific knowledge is essential for achieving greater inclusion and equity in education for Indigenous students.

This involves consulting with communities and respectfully using Indigenous knowledge best practices to increase aspiration and engagement of native students (Barnes et al., 2022). Additionally, linking cultural engagement and STEM research outreach may be more effective in Indigenous community contexts (Bonny, 2018). This helps students to develop an understanding of contemporary issues, such as natural resources, oceanography, earth sciences, and environmental sciences, from their community and culture, leading to greater relevance and persistence in science (Bruno et al., 2016; Carr et al., 2017). Furthermore, respectful collaboration between the university and scientific communities can be facilitated with the help of Indigenous knowledge holders through interactive science activities such as learning about food, medicinal plants, or the physics of spear-throwing, among others (Jamie, 2021).

Internal and External Factors

Some of the works mention that the family factor has a very important weight in the decision to study a university career in STEM, which is why it is essential to create a favorable social context of engagement between the university, families, and Indigenous communities to increase the relevance of STEM for them (Baker et al., 2021). Likewise, it is essential to take into account support networks beyond the family, the role of their cultural identity, and feelings of inferiority, symbolism, and marginalization as students from native peoples (Allaire, 2019). Indeed, personal and contextual factors are key as Indigenous youth self-identify as scientists and balance their identity with the many others they may have, opening up the possibility of majoring in STEM (Dabdoub et al., 2023). Some of the factors that stand in the way of students leaving home and entering STEM careers include cultural barriers, strong family obligations, traditional and/or religious restrictions, geographic barriers, financial barriers, a lack of role models, and academic deficiencies (Ingram et al., 2021; Kerr et al., 2018). In addition, if students do gain entry, they encounter the barrier that teachers are not sufficiently prepared in STEM (Kerr et al., 2018; Radmehr et al., 2020).

On the other hand, factors that help them to integrate into these disciplines include early participation in communities, such as friends and research groups, where academic culture is fostered while successfully negotiating their identities as Indigenous students and nurturing their academic talents (Silva et al., 2020b). In addition, the incorporation of Indigenous knowledge strengthens their identity as Indigenous students, thus promoting ethnic diversity in the university and in the professional sphere in addition to increasing their sense of belonging in STEM (Ingram et al., 2021; Silva et al., 2020a).

In summary, the positive results of the 24 studies identified can be seen in Appendix A.

Discussion and Implications

The systematic review of 24 diverse programs highlights the multifaceted nature of STEM education for Indigenous students, straddling both formal and informal educational contexts. The concept of intersectionality is crucial in understanding these programs. Indigenous students often navigate multiple identities and face unique challenges that intersect with their educational experiences. Programs that acknowledge and address these intersecting identities, such as the SEEDS programs at the University of Maryland, are pivotal in creating an inclusive and supportive STEM learning environment (Smith et al., 2017).

These multiple identities require specific efforts and the way of building and organizing the different initiatives, workshops, and mentoring programs identified specifically in the STEM areas has focused mainly on the methodologies used in each initiative. In the hybrid program proposal presented by the University of Virginia (USA), the use of the service-learning methodology has helped students not only to become interested in STEM areas but also to become aware of the usefulness of this knowledge in their communities and how they can complement it with their ancestral knowledge (Gibson et al., 2021). Also noteworthy is the active learning teaching approach presented in the 'Raising Interest in STEM Education' (RISE@Drexel) program by Drexel University (USA), which is developed through a pedagogy focused on "open-ended" problem-solving experiences, making the program a more engaging, practical, and supportive learning environment for indigenous students.

Likewise, in the Wabanaki Youth in Science (WaYS) program, multiple approaches to teaching and learning in STEM were introduced, and this multi-faceted approach (i.e., camps, community outreach, and mentored cultural and natural resource internships) has resulted in the recruitment and retention of Native youth in science fields. The Readiness, Recruitment, Retention, Role Modeling, and Research program focused on the inclusion of indigenous knowledge, specifically in the institutional setting. It promoted and valued diverse forms of knowledge, including competence or emphasis on the individual success of students, respecting and listening to their contextual needs. The AISES program, on the other hand, emphasizes the promotion of relational learning and the flexibility and adaptation of programs according to the students' backgrounds.

In terms of support initiatives, formal programs implemented by universities, with the help of researchers or professionals in the STEM field, stand out, allowing Indigenous students to actively participate in scientific activities and practical experiences where they are given the opportunity to develop skills and experiences in specific fields such as biology, computer science, chemistry, mathematics, engineering, geology, and astronomy. In spite of this, some studies criticize formal education for not incorporating other forms of knowledge (Ogawa, 1995). These programs, often backed by professional researchers and STEM experts, offer more than just content delivery; they represent a structured, yet evolving, approach to STEM education. However, in the programs reviewed in this study (Table 1), most presented positive results (Tables 2 and Appendix A), suggesting that formal schooling of Indigenous students helps the integration of their own Indigenous knowledge into science programs (Liu et al., 2023). Critically, these programs show an increasing trend towards incorporating Indigenous knowledge systems alongside conventional STEM education, challenging traditional boundaries and expanding the educational landscape.

On the other hand, informal programs, such as field trips and summer courses, are especially effective at helping students to strengthen their knowledge in specific STEM subjects, coinciding with those who indicate that these informal programs allow greater flexibility and creativity in problem-solving, fostering their interest, sense of enjoyment, and learning of science (Liu et al., 2023; Mack et al., 2012). The combination of formal and informal programs is essential for the inclusion of Indigenous students in STEM careers as it allows them greater integration in education, helping them to establish reciprocal relationships with their communities and the scientific knowledge they acquire in university (Zorec, 2022), finding a form of reciprocity in both directions.

Regarding the complementarity of Indigenous knowledge and Western scientific knowledge, a crucial factor for inclusion and equity in higher education in STEM for Indigenous students emerges. The incorporation of approaches that respect and value Indigenous knowledge is especially effective in expanding knowledge systems, finding value and new learning perspectives, making these communities part of the solution of contemporary problems from their culture. This is consistent with what Gillan et al. (2017) mention about the importance of Indigenous people being part of decision-making, to help shape and encourage support for initiatives that promote the educational success of Indigenous learners (Liu et al., 2023), in addition to showing them the benefits of acquiring and combining their scientific knowledge with their traditional knowledge to improve their communities. These results agree with Brown (2017), who mentions that the complementarity between cultural science practices and inquiry-based practices are useful in STEM learning. Therefore, the creation of hybrid programs developed in institutional contexts, such as internships, mentorships, and courses focused on science subjects, can transform higher education in STEM and drive native students to pursue these disciplines.

Fostering culturally responsive education is key to integrating native students' traditional and scientific knowledge throughout their educational journey (Aikenhead, 2001; Cobern et al., 1998; Dublin et al., 2014; Jin, 2021). The results of this review highlight the importance of considering cultural relevance in the design of programs targeting native students. It is essential to adapt these programs to the specific needs and contexts of Indigenous students, incorporating cultural aspects and traditional knowledge and always respecting and fostering their identity when integrating into STEM disciplines. By promoting the integration of traditional and Western scientific knowledge, these culturally relevant programs can enrich knowledge systems, provide value, and generate new perspectives for teaching and learning (Mack et al., 2012). For students, these programs provide them with the opportunity to identify with two cultures: that of their community and the culture of Western science and STEM. In this way, they contribute both to diversity in STEM and to the push for inclusion of Indigenous knowledge (Jin, 2021).

The implications resulting from this review and categorization of programs are directed towards researchers striving for educational equity for Indigenous students. This primarily emphasizes the importance of integrating indigenous knowledge into formal science education, implementing projects within safe micro-research environments, establishing mentoring programs and mathematics workshops, and developing culturally relevant programs that expand knowledge systems and foster new perspectives on teaching and learning. In doing so, this contributes to the diversity of STEM fields and the resurgence of indigenous knowledge, while respecting the culture and identity of the students.

Conclusion

In response to the research question of this study, it can be reported that different programs are aimed at Indigenous students for their access, retention, and follow-up in STEM careers. These programs are mainly divided into three groups: formal and informal programs, and those that are carried out in both contexts. The identified programs are further categorized into access, retention, and follow-up initiatives in STEM; approaches to scientific research; mentoring programs; internships in research laboratories; mathematics workshops; field activities; summer courses; and science ambassadors' programs.

As for the objective, after categorizing these programs it can be concluded that it is necessary to include the intersectional perspective in education. This promotes an inclusive, equitable, and quality education for all students, particularly for those who have been excluded from education for years, such as students from native peoples. On the other hand, it is necessary to discuss interculturality in education to recover the knowledge and cultural practices of native peoples and promote inclusion and equity in education, complementing it with Western scientific knowledge. It is important to make these students feel part of the community so that they can self-identify as scientists in their multiple identities and want to pursue STEM careers. Additionally, it recognizes the importance of the knowledge acquired in universities to support their communities.

In terms of contribution, the identified programs provide valuable information on how to motivate and encourage more Indigenous students to pursue STEM careers by reconnecting their culture with Western knowledge, helping them feel at home in both cultures, and making visible the importance of diversity in STEM. This can serve as a reference for educators, researchers, policymakers, and organizations interested in considering such an initiative.

Finally, it should be mentioned that the studies included in this review were limited to studies published in the Scopus and Web of Science databases, specifically studies focused on higher education. Other programs that were not published in these databases were not taken into account, which is a limitation. Positive results were reported in all the programs identified. In future studies, it is recommended to use other databases, theses, dissertations, government reports, and non-indexed academic journals, in addition to including programs with negative or null results.

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Appendix A

Positive outcomes

Authors	Positives outcomes
(Dabdoub et al., 2023)	The results suggest that fostering native students' identities as scientists within different educational settings is a fruitful avenue to increase the intention to major in STEM fields.
(Barnes et al., 2022)	NISEP has been an extremely enriching program for the inclusion of Aboriginal Australian and Straits Islander students and their communities in retention and progression into STEM careers. This program is distinguished by its respect for diversity, its commitment to listening to community members, and its focus on enabling program participants and their communities to play an active role in program development and implementation.
(Zorec, 2022)	Participation in supervised research activities in STEM had a significant impact on the academic and career aspirations of five Native Hawaiian college students as well as their perseverance in higher education. This suggests that providing students with hands-on opportunities to engage in individual research projects in collaborative settings promotes the development of research skills and the fostering of independent critical thinking.
(Ward et al., 2022)	The authors highlight the importance of supervised STEM research internships for Native American college students. Internship participants indicated that relationships with their mentors were critical to their personal and academic development.
(Baker et al., 2021)	Family engagement programs (FEPs) in STEM higher education at the University of Hawai'i at Manoa are culturally sustainable in that they provide opportunities to engage with Indigenous culture and language, prioritize non-Western epistemologies, and provide tools to navigate the dominant culture without losing identity. Responses to these activities from both students and their families have been resoundingly positive.
(Cannon et al., 2021)	The Native American Summer Mentoring Program (NASMP) offered by Utah State University was designed with the goal of improving retention and representation of Native students as well as fostering collaboration between mentors and mentees. Results obtained from this program at the Anthropological Water Heritage Project demonstrated that the virtual format of this project promoted effective cooperation between mentor and mentee, enabling rural students to participate in remote activities in the field of sciences.
(Gibson et al., 2021)	The Hybrid Summer Transition Program (HSTP) has demonstrated positive results in easing the transition of high school students to four-year colleges and universities, especially in STEM disciplines. The online courses contributed to familiarization with academic subjects and STEM career standards. On average, HSTP participants exhibited higher retention (85%) and graduation (73%) rates compared to their peers. Those who completed the online courses also showed a greater likelihood of earning outstanding grades in mathematics or chemistry.
(Ingram et al., 2021)	The results suggest that engineering students are more concerned about participating in activities within the engineering field that they perceive to be in conflict with their cultural, ethical, and/or spiritual identities compared to engineering professionals. Therefore, it is

	suggested that the identity of Indigenous students be encouraged and respected in program design.
(Jamie, 2021)	The positive aspect highlighted in this research relates to the recognition and preservation of Yaegl Country customary knowledge, and the implementation of a science leadership program, the National Indigenous Science Education Program has promoted the educational attainment and STEM participation of Aboriginal Australian youth.
(Phillips et al., 2020)	The program entitled 'STEM Spring Workshop', was primarily aimed at increasing Indigenous presence in STEM subjects, both at the University of Sydney and in a broader context. The design elements in the mathematics component of the STEM Spring Workshop were critical to its success in engaging and supporting student learning. Notable innovations included the two distinct streams, the inclusion of topics of interest, and the empowerment of teachers to freely adapt mode and content as needed.
(Radmehr et al., 2020)	The authors highlight the importance of creativity as a characteristic of effective teaching for Asians, and the highest percentage of reference to passion was for Maori students. The results imply that teachers should be well informed about these differences in order to improve the quality of their teaching and student learning in STEM areas.
(Silva et al., 2020a)	This review corroborates the impact that the incorporation of ethnic knowledge has on the identity of Indigenous students in college in STEM areas.
(Silva et al., 2020b)	The analysis showed that students who were successful in obtaining degrees had experienced early participation in communities that fostered an academic culture. These consisted of their families, teachers, and friends, and participation occurred throughout their lives as they successfully negotiated their identities as Indigenous and academically talented students.
(Allaire, 2019)	Participants explored the impact of support networks, which extended beyond the educational level of their parents, as well as feelings of inferiority, tokenism, and marginalization as being among the few Native Hawaiian students in STEM degree programs.
(Kerr et al., 2018)	The importance of one-on-one research mentoring is highlighted. These internships, even for periods as short as 10 weeks, provide island scholars with the understanding that they are scientists capable of completing baccalaureate studies and pursuing careers in STEM fields and higher degrees, especially in the life sciences. Former fellows from these programs are now teaching in schools and colleges on the islands and working for environmental agencies or NGOs back home.
(Bonny, 2018)	The impact of outreach initiatives is positively noted, and it is suggested that care be taken in program design and implementation, taking into account community priorities and local learning needs. The University of Saskatchewan's Science Ambassadors Programme places outreach staff, the 'science ambassadors', as two-way learners during their stays in remote schools in northern Indigenous communities, connecting cultural engagement with the STEM outreach mandate.

(Smith et al., 2017)	The development of first-year intervention programs designed for underrepresented students in engineering (such as African Americans, Native Americans, Hispanics, and women of all races) at the University of Maryland is positively highlighted. These include a summer bridge program, a mentoring program, and engineering-specific living-learning communities. These programs encourage student retention.
(Carr et al., 2017)	The Wabanaki Youth in Science (WaYS) program, targeting Native American youth in Maine, provides mentoring and life science training in a variety of settings, including camps, community outreach, and internships with cultural and natural resource mentors. WaYS has successfully transferred the integration of knowledge from cultural and natural resource mentors to their students, enabling them to understand contemporary natural resource issues from the perspective of their community and culture. This approach contributes significantly to greater relevance and persistence in the scientific arena.
(Trimmer et al., 2017)	Indigenous students, including graduates, indicated that cultural security, identity, and belonging, finances, family and community support, as well as the commitment of elders, were critical factors that enabled them to complete their studies.
(Leydens et al., 2017)	The University of Auckland in New Zealand established the 5 Rs program: Readiness, Recruitment, Retention, Role Modelling, and Research, with the clear objective of increasing engineering student enrolment and retention, as well as improving academic performance levels. Between 1998 and 2011, the 5 Rs program achieved significant success, increasing enrolment and retention, as well as improving performance levels, to the point where the academic performance of Maori students in engineering exceeded that of the non-Indigenous engineering student population. Several Maori students successfully completed master's and doctoral programs in engineering.
(Aspray, 2016)	AISES is one of the programs that has had the greatest impact on improving the pre-college education of Native American students by providing them with different stimuli and intellectual experiences to help them stay in STEM careers.
(Stevens et al., 2016)	The iSTEM program, a hybrid program that combines two strategic approaches—(1) in-school tutoring and (2) out-of-school informal science education experiences—fosters engagement and interest in STEM learning. Data from the iSTEM program indicate that it has been successful in engaging Native American students, increasing their interest in STEM, and strengthening their science beliefs.
(Bruno et al., 2016)	Summer bridge programs have proven to be an effective strategy for introducing prospective STEM students to geoscience careers, spanning disciplines such as oceanography, earth, and environmental sciences. At the conclusion of the week-long program, participants exhibited significant improvements in learning. Notably, five graduates of the program, including four Native Hawaiian students, earned geoscience degrees, representing 31% of the geoscience enrolment at the University of Hawai'i at Mānoa. These results suggest that collaboration with a minority-serving community college can be an effective and efficient strategy for increasing minority enrolment in the geosciences field.

(Christe et al., 2015)	A collaborative program was implemented between the Community College of Philadelphia and Drexel University designed to provide minority students with a STEM research experience. This approach combined academic education with the challenge of independent research in active laboratories. Results showed that students gained research skills, expressed increased interest in STEM, and many continued to work in the labs even after completing the program.