An Expert Panel Reports on STEM Education for Children and Youth from Marginalized Communities

A SSHRC-funded research collaboration between the Ontario Institute for Studies in Education and the Ontario Science Centre

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Researcher Biography

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A Note About Terminology

This study explores participant interpretations of ***STEM*** as an educational construct rather than as a combination of distinct subjects (science, technology, engineering, and/or mathematics). Part of the purpose of the study is to derive an understanding of what this group of educators mean when they speak about STEM education.

Throughout this report, the term ***marginalized learner*** is used to refer to children and youth from demographic groups that are underrepresented in STEM education and STEM careers in the Greater Toronto Area. Although it is recognized that contemporary education settings resist using descriptors (such as marginalized) before naming the learner, we use the term marginalized learner intentionally, emphasizing the culpability of educators and education systems in framing and reinforcing the social positioning of learners whose life circumstances often result in them being treated as peripheral or less significant than others in STEM education and STEM career settings.

The terms ***expert*** and ***participant*** are used interchangeably in this report. The terms refer to the STEM educational leaders consulted as part of the study. Each participant had a reputation for excellence in STEM education for and with marginalized learners. This reputation was evidenced through public recognition of the individual's work or the work of the organization with which they were affiliated; thus, from our perspective, they qualified as experts.

Within the text, we have used the generic terminology of ***learner*** and ***educator*** to move away from the notion that learning only happens in formal spaces with students and teachers or professors. Our participants work in a range of educational contexts, and we are aiming to contribute to a more holistic view of the educational spaces of learners.

List of Participating Organizations

For some organizations there was more than one participant, representing different departments within the same institution. Please note that the opinions expressed may solely be the opinions of the expert consultants and may not represent the views of the organizations within which they worked.

- ACTUA InSTEM
- Canadian Multicultural Inventors Museum
- Dufferin-Peel Catholic District School Board
- Helping Hands App
- hEr VOLUTION
- Let's Talk Science
- Ontario Science Centre
- Ontario Tech University
- Royal Ontario Museum
- SciXchange at Ryerson (Toronto Metropolitan) University
- STEAMLabs
- Toronto District School Board
- University of Toronto Engineering Outreach Blueprint/Engage programs
- Visions of Science
- York Region District School Board
- York University Science Engagement Program

Executive Summary

In March 2022, Ontario's Minister of Education, Stephen Lecce, announced revisions to the Ontario Elementary (Grades 1-8) Science & Technology curriculum. This new curriculum foregrounds STEM education as the central construct around which investigation skills are organized. Given the imminent implementation of this new curriculum (commencing September 2022), the study outlined in this report carries a sense of urgency as we seek to ensure that all learners have the necessary opportunities and educational conditions to allow them to thrive in STEM education.

The study described in this report employed a Delphi approach to solicit and collate the opinions of 20 educational leaders in the Greater Toronto Area (GTA) who have expertise in STEM education provision for learners from social groups that are underrepresented in STEM careers and STEM at higher education level. Government reports tend to focus on the underrepresentation of girls/women in STEM, but the experts consulted in this study broadened that perspective and cited income status and race as being even more impactful in influencing STEM education success for the learners they encounter. The experts tended to discuss marginalization in intersectional terms where many students face multiple conditions of disadvantage in relation to STEM education in the GTA. In line with concerns being expressed at the national level, experts hotly debated the impact of outdated, Eurocentric educational traditions, and asserted the importance of centring educational planning on local, community-based understandings of the learners' needs and interests.

Based on data gathered and refined during three rounds of surveys, the expert consultants participating in the study identified a set of 6 principles upon which STEM education should be based to facilitate more equitable provision for all learners. These principles are listed below in alphabetical order:

Educators need to continue building their capacity with respect to the use of digital technologies, as demonstrated in response to the COVID-19 pandemic

Educators need to recognise and be held accountable for prejudicial behaviours (such as racism and sexism)

Program evaluation feedback should come from learners, educators, and family/community members

Reform to teacher education and providing good quality teaching resources are fundamental aspects of increasing the engagement of marginalized youth

Representation matters: learners need to see mentors and role models who indicate that achievement is possible for people from their sociocultural background

There need to be more people from STEM marginalized backgrounds in leadership positions

In addition, the experts identified 10 high priority considerations for effective and equitable program planning; these are listed below in priority order:

1. Learners feeling supported and understood
2. Educators who understand the sociopolitical issues of marginalization
3. Nurturing natural curiosity
4. Reinforcing real world connections
5. Relatable and representative role models for the learners
6. Sustained educational experience (not just one-off workshops)
7. Bringing cultural knowledge into STEM
8. Iterative programming based on ongoing program evaluation
9. Learning in a space that is accessible and convenient for the learner
10. Use of inclusive terminology for all communications

These findings establish a baseline for program planning and program development, both for the organizations participating in the study and for the Ontario Science Centre (the research collaborator). To accompany the study, there will also be a community event hosted by the Ontario Science Centre so that findings can be disseminated across the region more broadly.

Study Overview

STEM education has been described as a priority in Canada for the last two decades.[1, 2, 3] According to the Council of Canadian Academies, STEM skills “open doors to a range of education and employment options, and are thus vital for all Canadians”.[3] Statements such as this make it clear that giving all students access to high quality, relevant STEM education is an equity concern since STEM is important for ALL Canadians.

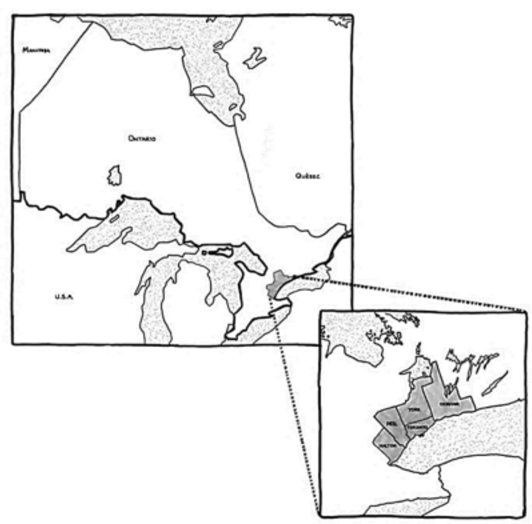
Another equity concern is that, in Canada, STEM graduates earn more than graduates of the arts, social sciences, humanities, or business fields.[4] This difference in salary is as much as 23% higher for men in STEM fields and 11% higher for women.[4] Given that STEM education has such an impact on career trajectories and earning potential, factors influencing STEM access require further investigation. The government of Canada has repeatedly focused their STEM education inclusion strategies on the need to increase participation of young women and girls in STEM, but more recently they have broadened this approach to focus on “members of underrepresented groups in STEM”,[5] but have not consistently named the groups of interest.

Against a backdrop of international (post)pandemic readjustment and re-examination of social justice agendas, the Ontario Science Centre has reaffirmed its mandate to broaden participation in STEM education. As a key component of that commitment, the Ontario Science Centre has partnered with the University of Toronto to explore the pedagogies, practices, and policies utilized and recommended by educational leaders in the Greater Toronto Area (GTA) who have expertise in STEM education provision for learners who have been marginalized in systems of STEM education. The study invited 20 of the region’s leading STEM educators, each with extensive experience of working with and for marginalized communities, to contribute their perspectives on and suggestions for improving equity in STEM education in the GTA.

The Greater Toronto Area (GTA)

According to the City of Toronto’s official website,[6] the Greater Toronto Area (GTA) is a somewhat flexibly defined collection of municipalities that include Durham, York, Peel (consisting of Mississauga, Brampton and Caledon), and Halton Regions, surrounding the City of Toronto within the Lake Ontario ‘Golden Horseshoe’ (see Figure 1). The Golden Horseshoe is so named because of its shape as it wraps around the western end of Lake Ontario; gold is historically associated with the wealth and prosperity of the region. At the core of this region, the GTA is renowned for being an area of intense economic/business connectivity. Based on the government of Canada’s census measures of diversity, the GTA is described as one of the most diverse regions of the world. The government of Canada identifies the following dimensions of diversity: age, living conditions, household/family characteristics, personal/household income, birthplace, immigration history, citizenship, religion, ethnic origin, Indigenous identification, visible minority status, language, educational background, and work situation.[7] The extensive history and experience of the GTA with diversity makes it an ideal location within which to study equity concerns.

Figure 1. The Greater Toronto Area within the province of Ontario.



Research Questions

The study explored two research questions:

1. How is the concept of STEM education defined and operationalized by STEM educational leaders working with marginalized learners in the GTA?
2. What are the key educational priorities identified by leaders of programs that provide STEM education to marginalized learners in the GTA?

The Research Approach

For this study we used the Delphi technique to solicit expert opinion on the given topic through a series of surveys or questionnaires, interspersed with summarized information. The Delphi approach requires the group of experts to provide feedback on each other's opinions until stability in responses is reached.[8] The methodology is particularly well suited to the study of complex issues. Individuals who have extensive experience and expertise in a given field are surveyed so that areas of consensus may be distinguished from context-specific particularities.[9] The key strength of the Delphi approach is that ideas are gathered from a group of experts remotely, mitigating the impact of power dynamics and rhetoric that usually prevail in face-to-face situations.[10] Appreciating that the number of individuals who are recognized as experts in a given field in a defined geographic location is likely to be small, the researchers Linstone and Turoff suggested that the optimal sample size of participants for this kind of study is between 10 and 25 persons.[9]

Research Participants (The Experts)

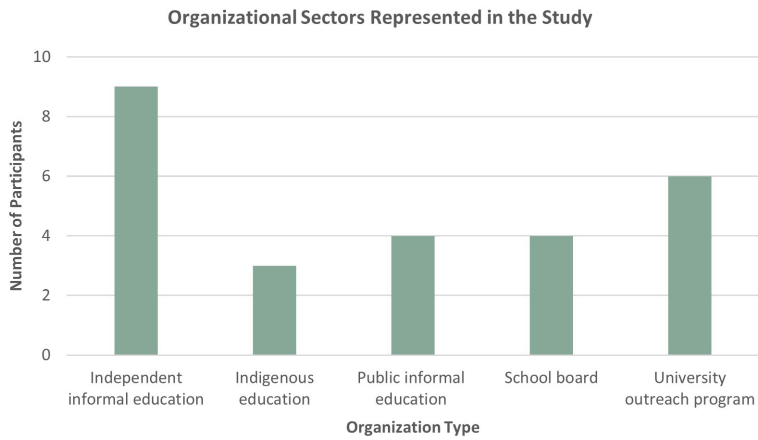
Although we acknowledge that individuals participating in the study may not identify themselves as experts in the field, our invitations to participate were based on their leadership in a program or system of STEM education that focused on learners from demographic groups that are typically marginalized in STEM education and careers. It was important that the participants were leaders in initiatives labelled as STEM, as opposed to science, technology, engineering, or mathematics individually. Participants were recruited based on one of the following conditions: being known for working with marginalized learners (as identified by members of the Ontario Science Centre); gaining public recognition for their work in STEM education for marginalized learners (as publicized through an Internet-based media outlet); or being recommended by a previously invited participant. Before extending invitations to contribute to the study, Internet searches were conducted to check that each participant had a clear connection with STEM education in the context of marginalized learners. This connection was verified by participants themselves after receiving the study's information/consent document.

Experts from formal and informal STEM education settings within the GTA came from five main institutional contexts:

i. Leaders of independent, informal STEM education organizations
ii. Leaders in Indigenous STEM education (in formal or informal education settings)
iii. Leaders in public informal STEM education institutions
iv. School board STEM leaders
v. Leaders of university STEM outreach programs

Our aim was to invite 20 educational leaders to serve as expert consultants in the study, with a representation of at least 3 leaders from each sector. Appreciating that invited participants were people in leadership positions within their organizations, we anticipated some attrition (due to the busy work schedules of the participants and the added pressures of the pandemic situation), but we hoped that participation would never fall below 10 (which might undermine the integrity of the Delphi methodology). The list of affiliations for the 20 participants starting the study is illustrated in Figure 2 below.[i]

Figure 2. Organizations represented by the 20 research participants.



Participants indicated the length of time working in the area of STEM education for marginalized learners. All participants had at least 3 years of experience working in this field, with the majority having 6 to 10 years of experience; a couple had been working in STEM education for marginalized youth for over 20 years. Figure 3 illustrates the number of years of experience that participants brought to the study. Additional participant information (such as gender, age, or organizational details) was not collected.

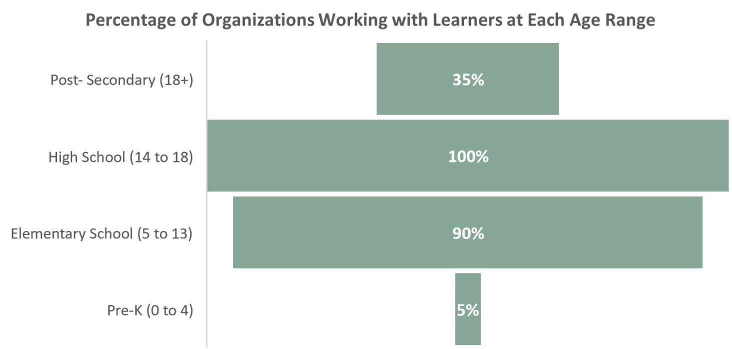
Figure 3. The number of years of experience in STEM education for marginalized learners of the expert participants.

i The total number of participants represented exceeds 20 as some individuals had affiliation with more than one sector.

Marginalized Learners

Participants provided details of the age ranges of learners with whom they were working or had worked. These are summarized in Figure 4. All participants worked with organizations that support learners in the high school category. In addition, 90% of participants worked with children of elementary school age. One third of the participants also worked with the post-secondary age range and only one participant worked within an organization supporting STEM education for pre-K learners.

Figure 4. The age ranges of learners in the various organizations within which participants worked.



The experts also identified the marginalized groups served by their organizations. These are listed below as factors contributing to marginalization of learners in STEM education. The list identifies factors in rank order of the frequency with which they were mentioned by the research participants, from most frequent to least frequent (note that some factors have equal ranking):

1	Socio-economic/income status
2	Race
3	Gender/sex
4	Indigenous identification
=5	Immigration status
=5	(Physical) disability
=7	Ethnic origin
=7	Language
=7	Remote/rural living
=7	Special educational needs/exceptionalities
=11	Belief system/worldview
=11	Sexuality

For some of the experts, there seemed to be some discomfort in naming the demographic characteristics of marginalized learners for fear of stereotyping or reinforcing deficit narratives, but many participants described it as important to identify and call out biases and prejudices within our systems of education. Several participants highlighted the intersectionality of factors embodied by their learners. The race category most frequently referred to was Black. There was a lot of commentary about bias based on systems with a colonial heritage that have established what one participant described as an "old boy's network" of policies and practices; this was described as resulting in a narrow representation of ways of knowing, leading to inappropriate or non-inclusive pedagogies. Additional concerns that were described as leading to learner marginalization were low teacher expectation and the lack of role models.

Overview of the Research Methods

The project was conducted over a 10-month period and utilized 3 rounds of individual Internet-mediated surveys. After each survey, responses were gathered, analyzed, refined, and summarized. After the first and second surveys, the data summaries were sent to participants and subsequent surveys asked them to evaluate the comments contained in the summaries. This process helped the STEM education leaders to scrutinize the ways in which they and others in the field define effective STEM education and the constraints faced by students belonging to demographic groups that are underrepresented in STEM higher education and careers.

A participant webinar was held prior to circulation of the third survey. This allowed researchers to ensure that participants had a good grasp of the research process and understood how the findings were generated so that they were fully informed about what the data showed before completing the final survey. The webinar was also used to animate participant words represented in the summary document so that the researchers could get a more lucid clarification of the opinions represented in the data.

Figure 5 represents the overall research process consisting of 3 rounds of data collection/refinement that included both quantitative and qualitative components. There was some attrition of participants from 20 completing Round 1, 16 completing Round 2, to 14 completing Round 3.

Figure 5. Overview of the research process.

The Study Surveys: Data Gathering and Analysis

Traditionally, Delphi studies have been used by corporations to complement other systems analysis approaches so that operations can be improved. Linstone and Turoff asserted that Delphi-mediated research studies are effective in the comprehensive examination of human perspectives within an array of system contexts and tend to explore one or more of three knowledge areas: technical issues, organizational concerns, and personal connections.[9] Technical issues consider the day-to-day strategies and operations that occur within a given system. Organizational perspectives are those that consider the high-level decision-making about an institution. Personal concerns refer to the in-the-moment space of interpersonal relationships. This study captures input on all three of these dimensions in the introductory survey, acknowledging that participant responses may prioritize one category over the others. Applying this framework to the particularities of educational contexts, we adapted the Delphi categories. Thus, the technical dimension was reinterpreted as the day-to-day ***practices*** of an educational institution. Organizational viewpoints were seen as opinions concerning the ***policies*** that an organization or program may be subject to (based on both internal and external/societal decision-making). The personal perspectives were viewed as the more intimate ***pedagogies*** that are employed and experienced in educational settings; this included consideration of interpersonal relationships.

Round 1 Data Gathering

Participants were presented with the following questions to explore STEM education in the dimensions of practices, policies, and pedagogies. In addition, questions were added to specifically acknowledge that definitions of the term STEM may vary from one organization to another and that the COVID pandemic may have influenced perspectives on prior operations.

1. What is your operational definition of the term 'STEM education' (what does it include, what is not included)?
2. Describe the characteristics of the learners who tend to be marginalized in STEM education pathways in your sector. What are some of the reasons for their marginalization? What are the expectations for their futures in STEM?
3. What factors do you consider when planning programs, interventions or supports for marginalized learners, and how do you prioritize these factors (what is most important)?
4. Who should take responsibility for the changes that are needed in STEM education of marginalized learners? Should this be a matter of personal, organizational, local, regional, and/or national responsibility? Explain and prioritize responsibilities as far as you are able.
5. What do you see as the greatest limitations to enacting your ideal form of STEM education in your organization or elsewhere?
6. In your experience, what conditions would promote effective engagement of marginalized learners in your sector with STEM education (include physical conditions, qualities of educators, permanent and consumable resources, time, space, human resource considerations, etc.).
7. How do you evaluate the effectiveness of STEM education strategies for marginalized learners (personally or within your organization)?
8. Describe how the pandemic has impacted STEM education provision for marginalized learners in your organization (describe long- and short-term impacts as well as positive and negative lessons you have learned).

Participants were also provided with a free response box where they could record any other thoughts they had about STEM education. These survey questions were administered online using a secure University of Toronto Microsoft Forms survey environment.

Round 1 Data Analysis

The experts generated over 13,000 words of commentary (an average of more than 650 words for each participant) which was coded according to the initial themes: definitions, policy, practice, pedagogy, and COVID impact. Our aim was to classify every assertion made by every participant. This led us to the generation of more nuanced coding categories that described different levels of educational influence, from the national and federal policy level of STEM education to discrete program-level decisions. After classifying every participant comment, statements were combined and reworded to accommodate the sentiments of multiple experts expressing the same idea. The result was a set of 110 data points that we organized into 60 statements, grouped under 6 categories, and 50 ideas for effective programming.

Round 1 Results

See Figure 6 for the full list of statements generated from the Round 1 data. These statements formed the substance of the Round 2 survey.

Figure 6. Statements generated from Survey 1 of participant data, organized according to category.

Purpose and focus of STEM education	
A learner's potential in STEM can be judged by their mathematics performance	STEM education requires integration of all four subjects: science, mathematics, engineering and technology
Interdisciplinarity/transdisciplinarity is the key to effective STEM education	STEM education should include the arts and humanities
STEM education is any learning situation that touches on science, technology, engineering or mathematics	STEM programs should include connections to the environment and nature
STEM education mainly concerns applied science and technology	The purpose of STEM education is to foster creativity and innovation
STEM education must involve hands-on approaches	Western STEM perspectives should be introduced as a subset of the many ways of coming to know in the world

Societal and systemic impacts on STEM education	
Curricula based on traditional subject divisions and grade structures limit the effectiveness of STEM education	STEM education program investors are more interested in short term optics than long term impact
Industry has a responsibility to promote equity in STEM education because they dictate the demand for STEM employees	The digital technology divide became more obvious during the pandemic
Industry leaders influence participation in STEM education because they exert power through their investment in programs and learners	The pandemic has exacerbated and made more evident the inequities that exist within systems of STEM education
Mathematical modelling and problem-based approaches are leading innovation in STEM education	The precarious nature of funding reinforces the need for a diversified funding base with multiple funding sources
Race-based STEM education statistics should be collected	There is widespread commitment to Eurocentric, prejudicial traditions of teaching and learning in STEM education

STEM education leaders and policymakers	
Industry professionals need to have greater input in training STEM educators and delivering STEM programs	STEM education leaders and educators need ongoing diversity and inclusion training
It is the responsibility of those in dominant positions to use their voices and power to make changes that are needed for the marginalized learners in their jurisdiction	The power to determine programming and allocate resources needs to be held at the local level
Reform to STEM education policy begins at the national or provincial level with government funding	There need to be more people from STEM marginalized backgrounds in leadership positions
Reform to teacher education and providing good quality teaching resources are fundamental aspects of increasing the engagement of marginalized youth	To make program planning effective, STEM education leaders and policymakers first need to acknowledge the enduring influence of colonization
Representation matters: learners need to see mentors and role models who indicate that achievement is possible for people from their sociocultural background	To support learners who are marginalized, STEM education providers in different sectors need to cooperate and collaborate more

Marginalization of learners in STEM education

Bridging and access programs are needed because if students get low grades at any point in their formal STEM education, pathways for continuing their education and potential for STEM employment quickly close	Learners need to appreciate the power of the knowledge of their own community
Educators need to recognise and be held accountable for prejudicial behaviours (such as racism and sexism)	Low educator expectations are steeped in histories and cultures of bias and prejudice
For career options to remain open, marginalization of learners must be reversed before the end of high school	Outdated traditions focused on male learners of European origin create a hostile environment that marginalizes many learners
Income and education level of adults in the household are the strongest indicators of potential learner marginalization	There are no fundamental learner qualities that make a student unable to pursue STEM education or careers in STEM fields
Learners are marginalized through lack of contact with STEM professionals or people with STEM skills	When educators do not challenge societal norms, learners who do not identify as mid to high socioeconomic status, European descent, English-speaking, physically and mentally uninhibited in society, boys/men, etc. are pushed to the margins

Practices of educators and program planners

Generally, evaluation strategies have not been as well defined as the various programming approaches	Program evaluation feedback should come from learners, educators, and family/community members
Individual subjects, such as science or math, are seen as representing STEM; the other components are less important	Programming must be specialized to the particular learner group identified
It is essential that educators really get to know the learners over a sustained period of time	The effectiveness of a program in a given community is best indicated by participation rates
Measuring STEM skill level is difficult	The greatest limitation to effective programming is money
Positive attitude changes of learners are good indications of effective programming	The short-term nature of funding is the biggest problem for sustainable programming

Impact of the pandemic on STEM programs

Educators have been increasing their capacity with respect to use of digital technologies	The ability to redirect finances (since food, travel, and some materials were no longer needed) was a bonus
Existing programming could not be replicated online; new approaches were required	The increased use of technology has made space for relating and engaging learners in different ways and introducing resources that are more tailored to individual needs
Learners who have been marginalized maintained their desire for out-of-school program connection	The lack of experiential/hands-on learning opportunities was very limiting
Providing computers and Internet access were significant challenges	There has been increased contact with remote learners
Relationship building with learners was greatly interrupted	There have been strong connections built with learners' families

The experts' 50 ideas for effective programming are listed below, alphabetically.

- A learning context focused on engagement and enjoying the learning experience
- An atmosphere of care
- Appropriate compensation for community-based STEM educators
- Bringing cultural knowledge into STEM
- Covering expenses that facilitate access to learning such as food and/or transportation costs
- Decentering the white, male image (and history) of STEM
- Design thinking as the focal point of learning
- Developing learners' leadership skills
- Digital technology to support learning
- Education and career trajectories of learners need to be followed to see if impact is sustained
- Educators from similar backgrounds as learners
- Educators who are specialists in the field
- Educators who understand the sociopolitical issues of marginalization
- Informal/anecdotal evaluation approaches
- Inquiry-based learning
- Introduction to potential STEM careers
- Iterative programming based on ongoing program evaluation
- Land-based approaches
- Learner-defined learning goals (within the scope of the topic)
- Learners feeling supported and understood
- Learners having the opportunity to communicate findings and receive feedback
- Learners meeting real STEM professionals in the workplace
- Learning in a space that is accessible and convenient for the learner
- Local, learner-centered planning for programs
- Locally-relevant curriculum
- Mechanisms for family members (who are not enrolled in the program) to connect with STEM learning
- Multimodal support materials, including videos, images and simulations (not just written instructions)
- New, rather than pre-owned materials and technology equipment
- No age restriction within learner groups
- No financial burden on the learner
- Nurturing natural curiosity
- Ongoing and accountable inclusion/cultural awareness training or educators
- Pedagogy centered around the lived experiences of the learners
- Program based on relevance and learner interests
- Program graduates serving as leaders (developing leadership skills)
- Promoting learner collaboration
- Providing devices for at-home use
- Reinforcing real world connections
- Relatable and representative role models for the learners
- Responding to community-identified needs/wants
- Setting clear goals for the program
- Small self-defined learner groups
- Social ethics reinforced through the program
- Strengthening learner community connections
- Survey-based evaluations completed by all leaders, learners, and partners before, during and after the program
- Sustained educational experience (not just one-off workshops)
- The educator acts as a project manager rather than a 'teacher'
- Use of inclusive terminology for all communications
- Use of third-party organizations to support program evaluation
- Using peer mentors and educational facilitators rather than the 'teacher' being the leader of everything

Round 2 Data Gathering

The survey for Round 2 of the study contained quantitative and qualitative components. Participants rated each of the 10 statements within each category using a 7-point Likert-type scale where the rating descriptors were: strongly agree; agree; somewhat agree; neither agree nor disagree; somewhat disagree; disagree; and strongly disagree.[ii] In addition, statements within each set of 10 were ranked. Finally, participants were asked to provide further explanation and/or clarification of their responses and perspectives in written comments.

In addition to the 6 statement categories, a collection of the participants' 50 ideas for effective programming was presented at the end of the survey. These ideas were rated by the experts on a 7-point Likert-type scale where the categories were: highest priority; important; this matters; this does not really matter; very low priority; not important at all; and not applicable. Participants were also provided with an opportunity to add commentary regarding the choices made in this portion of the survey.

Round 2 Data Analysis

Likert-type rating of statements

Since we were looking for points of consensus among the group of experts, we calculated mean, mode and median as well as standard deviation for all Likert-type sections of the survey, assigning scores of 7 to strongly agree responses, down to 1 for strongly disagree. Statements were given consensus status if there was no disagreement expressed by any of the participants and if the mode and median scores were 6.0 (out of 7) or above. We also required standard deviations of 1.0 or below to indicate that the strength of agreement was well clustered around the mean score so that we could be more secure in the reliability of our assertions about consensus.

Statement ranking

The statement ranking exercise allowed us to confirm that the statements receiving a high score via the Likert-type section of the survey were also considered to be of high importance by the participants. In this ranking section, the statement of strongest agreement was given a score of 10 and the least given a score of 1. Therefore, we refined the list of consensus statements by adding a further requirement that all statements of consensus standing should also have been ranked in the top 4 statements in their category in the ranking sections of the survey, with median above 7.0 (out of 10).

Rating programming suggestions

Each of the 50 ideas for effective programming was scored according to the rating given: highest priority (6); important (5); this matters (4); this does not really matter (3); very low priority (2); not important at all (1); and not applicable (no score awarded). Mean, mode, median and standard deviation were calculated for each idea rated.

Free-response commentary

Overall, the comments for Survey 2 consisted of over 8,000 words and were used to provide explanations for the ranking and rating patterns observed in other parts of the survey.

ii The statement rating method is described as Likert-type because statements are evaluated independently, rather than using a composite score of a cluster of statements to determine a perspective (as might be used in the traditional Likert scale approach).

Round 2 Results

The findings emerging from Survey 2 are laid out below in their various categories. It is noted that some themes stretched across more than one category, and explanations often utilized ideas from more than one category. As a result, a list of 9 consensus statements fulfilling the analytic criteria above is presented at the end of this section.

The purpose and focus of STEM education

There was a lot of diversity in the ways in which participants described what STEM education is. The only statement with a strong indication of consensus agreement, as indicated by the low standard deviation and high mean, mode, and median is the statement ***STEM programs should include connections to the environment and nature***. Every participant indicated agreement with this statement, but no-one ranked this at the top of their scale of agreement, indicating that this is a statement with which many agree, but which few would take as a top priority. Balancing science, technology, engineering, and mathematics did not seem to be a key priority in defining STEM, but it was also not appropriate to reduce STEM to science and technology alone (as indicated by the strong disagreement with the statement ***STEM education mainly concerns applied science and technology***). There was strong support for inter-/trans-disciplinarity being a fundamental approach in the way that STEM education is designed; the only disagreement came from a participant who agreed with the importance of interdisciplinarity, but only to the extent that the learners and their communities desire it. The sentiment of learner and community centring was repeated throughout the survey and indicated a desire for this to become the guiding principle for STEM education for and with learners who have been marginalized. Most participants linked STEM education to opportunities for expression of creativity and potential for innovation; these concepts went hand-in-hand with real-world connections and problem-based/inquiry approaches, many of which are hands-on with a more recent emphasis on technology-mediated learning. Another theme that was woven throughout the comments section was that of challenging the dominance of Western perspectives and making concerted efforts to decolonize approaches. This will be discussed in more detail later in this document. Figures 7 and 8 summarize these points.

Figure 7. Participant rating of statements about the purpose and focus of STEM education.

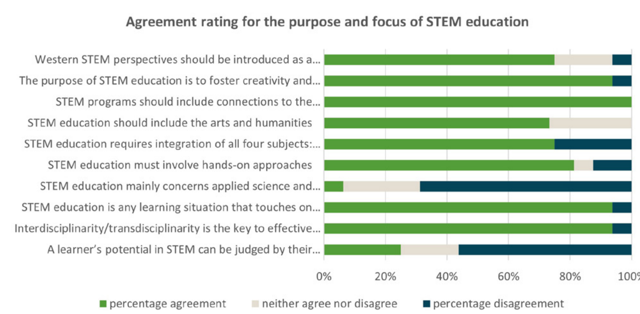
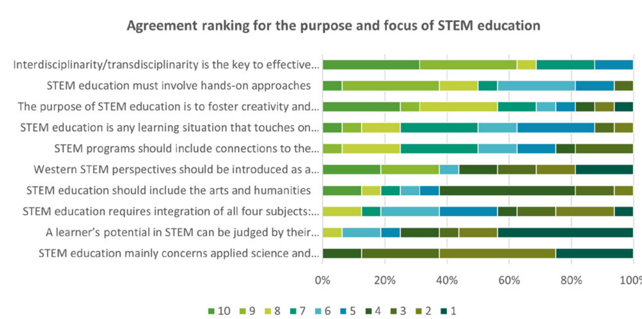


Figure 8. Participant ranking of statements about the purpose and focus of STEM education.



Societal and systemic impacts on STEM education

There was a fairly high level of agreement in the ways that participants described the societal and systemic impacts on STEM education. The statement ***Curricula based on traditional subject divisions and grade structures limit the effectiveness of STEM education*** carried top ranking and rating positions, and commentary supported the embrace of interdisciplinarity as a way forward for curriculum development. Another statement (***The digital technology divide became more obvious during the pandemic***) reinforced concerns about a digital technology divide within the population that was limiting the scope of STEM education for many learners. The inequities of technology-mediated learning were most evident for participants whose organizations had to make an abrupt shift to online interfaces with learners. In these circumstances, issues raised were associated with Internet access and speed as well as supply of hardware. However, for some learners, the use of digital interfaces improved engagement (this will be addressed in more detail in a later section). One key point of disagreement was the way in which the Eurocentric history and sociocultural legacy of STEM education should be treated. Most participants saw a confrontation of STEM knowledge traditions as a fundamental component of decolonizing contemporary approaches, whilst those who disagreed presented concerns about over-emphasis of the legacy that may hinder forward movement. Funding and investor experiences seemed to be very varied within the group of experts. Figures 9 and 10 summarize these points.

Figure 9. Participant rating of statements about societal and systemic impacts on STEM education.

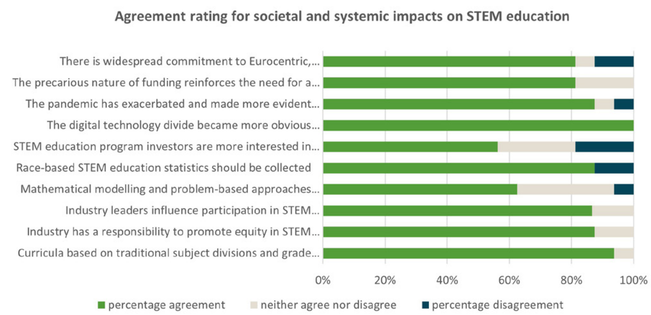
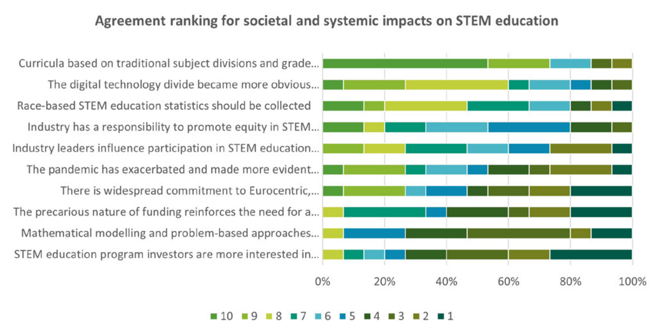


Figure 10. Participant ranking of statements about societal and systemic impacts on STEM education.



STEM education leaders and policymakers

As with the previous statement set, there was very little disagreement with any of the statements with this group of assertions; the means, modes, and medians of all but one of the statement ratings were above 5.5 (out of 7). With such a high level of agreement, it is not surprising that it was difficult to derive a clear sequence of prioritization for the statements. Three statements appeared in the top half of both rating and ranking scales with standard deviations less than 1.0 in the rating scale (***Representation matters: learners need to see mentors and role models who indicate that achievement is possible for people from their sociocultural background; There need to be more people from STEM marginalized backgrounds in leadership positions;*** and ***Reform to teacher education and providing good quality teaching resources are fundamental aspects of increasing the engagement of marginalized youth***). These statements can be summarized as reinforcing the importance of employing educators who understand the complex positionings of marginalized learners and who are able to work with learners to create high-quality educational experiences. Participant commentary reinforced the importance of hearing from and acting upon the experiences and insights of marginalized learners and those who have lived experiences of marginalization. The lowest ranking and rating were given to the statement referring to receiving input from industry professionals; there was hesitancy expressed with respect to the potential for corporate interests to interfere with educational objectives. The statement emphasizing the need for reform of government policy elicited explanations that illustrated a desire for government action but called for educators to be responsible for doing what they can in their own local contexts in the meantime. The notion of STEM education providers in different sectors cooperating and collaborating was rated high but placed low on the list of priorities; again, suggesting that, although some things (such as inter-sector collaboration) are seen as important, finding time and resources to make them happen cannot always be prioritized. Figures 11 and 12 summarize these points.

Figure 11. Participant rating of statements about STEM education leaders and policymakers.

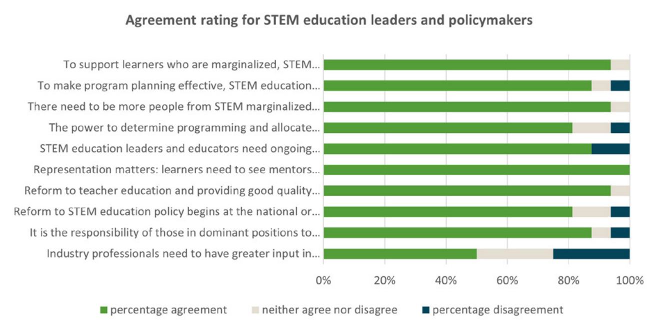
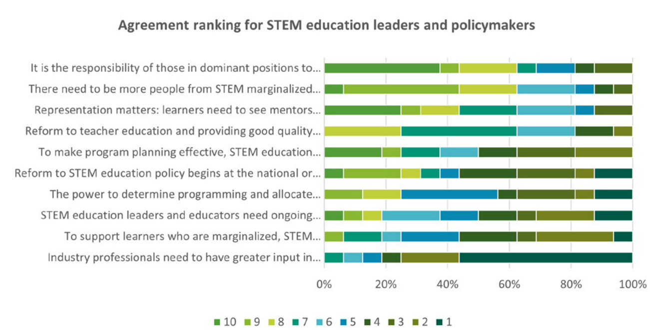


Figure 12. Participant ranking of statements about STEM education leaders and policymakers.



Marginalization of learners in STEM education

Two statements were ranked and rated at the top of the statement set for this theme and garnered impassioned explanations for their prioritization (***Educators need to recognise and be held accountable for prejudicial behaviours [such as racism and sexism***) and ***Bridging and access programs are needed because if students get low grades at any point in their formal STEM education, pathways for continuing their education and potential for STEM employment quickly close***). Similarly, a single statement was both rated and ranked lowest: ***Income and education level of adults in the household are the strongest indicators of potential learner marginalization***. A lot of ambivalence was shown with regard to this latter statement, as indicated by the high standard deviation in the rating scale (1.86). Although there was broad concern for educator biases and recognition of the ways in which educator prejudices can be revealed in low expectations and reinforcing limiting beliefs in learners, a number of participants added to concerns about educator prejudice by stating that learners and their peers also need to be held accountable for prejudicial behaviours. Commentary associated with the need for bridging and access programs provided further explanation about the importance of complementary programs that give learners multiple opportunities to re-engage with STEM, particularly after bad experiences. The notion of learning being connected to community was also rated high but ranked towards the middle of the statements; again, indicating that what is desired is not always what is prioritized. Figures 13 and 14 summarize these points.

Figure 13. Participant rating of statements about marginalization of learners in STEM education.

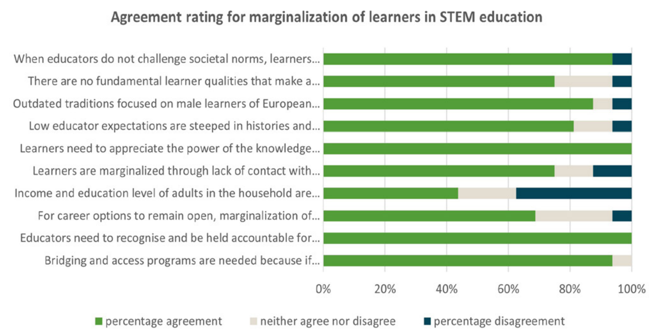
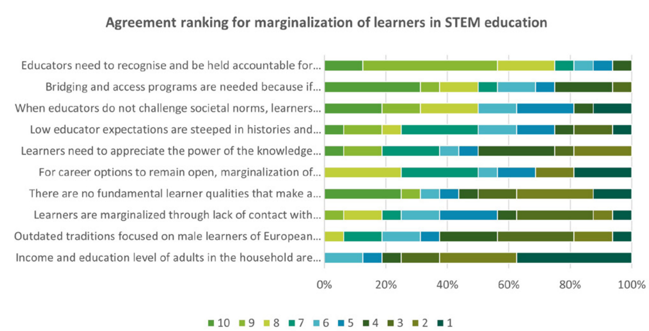


Figure 14. Participant ranking of statements about marginalization of learners in STEM education.

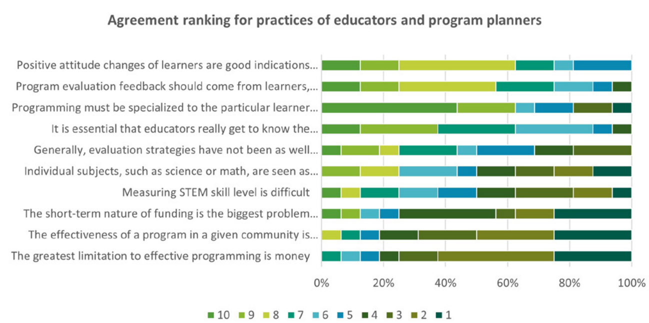


Practices of educators and program planners

One statement elicited agreement from all participants: ***Program evaluation feedback should come from learners, educators, and family/community members.*** Although it was clear that this was not always the evaluation approach taken by organizations, participants stated the importance of gaining feedback from multiple avenues to gain a community-level understanding of the impact of a program as a continual process of program development, given that learners and their needs change over time. This response reinforced assertions made in other sections about the priority of learning from and with(in) community. Many participants highlighted the challenges associated with implementing effective program evaluation, but others linked these challenges to ill-defined program goals. A number of participants associated funding constraints with the restricted implementation of different program planning options. There was a widespread desire for sustained program planning but the feasibility of this was linked to the (in)security of program funding. Funding structures for different programs seemed to vary but one participant suggested that one approach moving forward might be for organizations to start partnering and collaborating so that expertise and resources could be shared. Above all, participants wanted learners to feel positive about the learning experience. Figures 15 and 16 summarize these points.

Figure 15. Participant rating of statements about practices of educators and program planners.

Figure 16. Participant ranking of statements about practices of educators and program planners.



Impact of the pandemic on STEM programs

The variations in program experiences during the pandemic seemed to reflect the organizational structure within which each program operated prior to the pandemic. Almost all participants indicated that ***Educators have been increasing their capacity with respect to use of digital technologies***. Many comments associated a new era of digital learners with a need for educators to catch up in developing more flexible mindsets and greater breadth of knowledge regarding what it means to teach in ways that fully engage learners. Participant comments vividly illustrated the great lengths to which educators will go during challenging circumstances to ensure that the needs of learners are put first, and some semblance of stability is preserved for the learner. A number of participants described the polarization of experiences for learners and educators during the pandemic. This was also seen in responses associated with making connections with the families of learners; some of these were facilitated by the digital interface, but others felt that relationship building with, and engagement of, remote learners were challenged by the computer-mediated context. Figures 17 and 18 summarize these points.

Figure 17. Participant rating of statements about the impact of the pandemic on STEM programs.

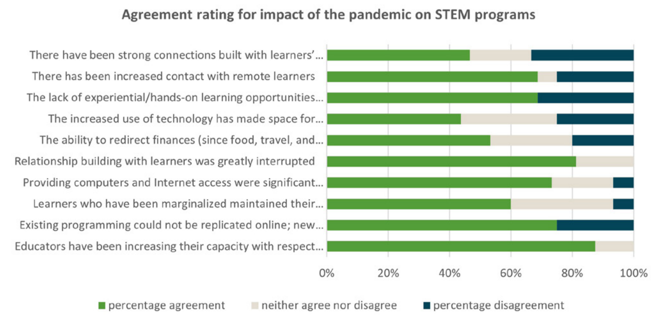
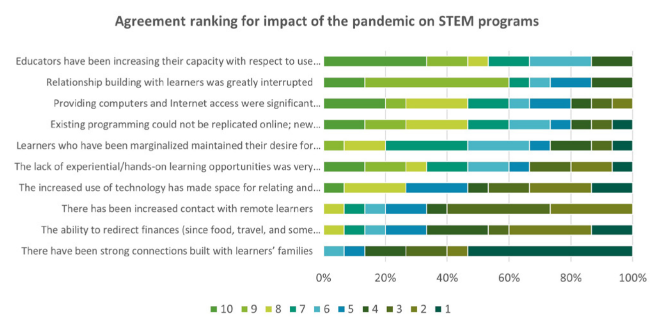


Figure 18. Participant ranking of statements about the impact of the pandemic on STEM programs.



Round 2 Summary

Consensus statements (in alphabetical order)

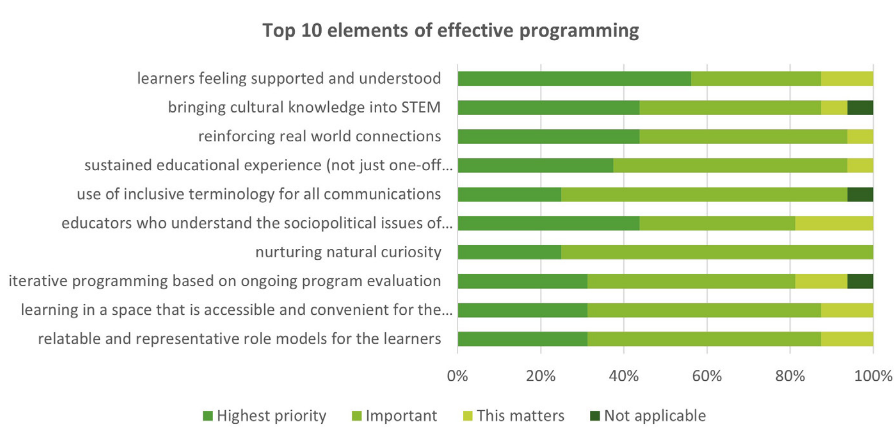
- Bridging and access programs are needed because if students get low grades at any point in their formal STEM education, pathways for continuing their education and potential for STEM employment quickly close
- Curricula based on traditional subject divisions and grade structures limit the effectiveness of STEM education
- Educators have been increasing their capacity with respect to use of digital technologies
- Educators need to recognise and be held accountable for prejudicial behaviours (such as racism and sexism)
- Program evaluation feedback should come from learners, educators, and family/community members
- Reform to teacher education and providing good quality teaching resources are fundamental aspects of increasing the engagement of marginalized youth
- Representation matters: learners need to see mentors and role models who indicate that achievement is possible for people from their sociocultural background
- The digital technology divide became more obvious during the pandemic
- There need to be more people from STEM marginalized backgrounds in leadership positions

Key elements of effective programming (in priority order)

In this section, many statements were rated as 'high priority' by participants. To be listed as a top priority in this summary, statements needed mean ratings above 5.00 (out of 6), no ratings indicating low importance, and standard deviations below 1.00. The top 10 statements fulfilling these criteria are listed below and illustrated in Figure 19.

1. Learners feeling supported and understood
2. Bringing cultural knowledge into STEM
3. Reinforcing real world connections
4. Sustained educational experience (not just one-off workshops)
5. Use of inclusive terminology for all communications
6. Educators who understand the sociopolitical issues of marginalization
7. Nurturing natural curiosity
8. Iterative programming based on ongoing program evaluation
9. Learning in a space that is accessible and convenient for the learner
10. Relatable and representative role models for the learners

Figure 19. Participant rating of statements about the key elements of effective programming.



Round 3 Data Gathering

The third round of the study served as a confirmation stage of the research. The findings outlined above were circulated to the participants prior to their attendance at a webinar meeting. The webinar was used by the researchers to ensure that all participants understood how the data were generated and had opportunity to discuss any points of confusion or disagreement. The webinar was presented in two parts; the first was a presentation by the lead researcher detailing the research methods and modes of data analysis conducted in Surveys 1 and 2. During the second part of the webinar, participants were invited to provide questions or comments regarding the data summary shared via the webinar's chat or Q&A function, after which, they were invited to speak about their comment in more detail, if desired. Participants were signed into the webinar anonymously and were able to share their thoughts vocally but only the researchers were visible to the group. After exchanging ideas with one another, Survey 3 was circulated. This survey asked each participant to comment on the importance of the 9 consensus statements derived from Round 2 of the study. The participants then ranked the 10 key elements of effective programming derived in Round 2 of the study.

Round 3 Data Analysis

Whole group webinar

The webinar was not recorded but researchers made note of any points of discussion raised by participants and cross-checked them against comments made in other parts of Survey 3.

Review of consensus statements

In Survey 3, participant commentary on each of the 9 consensus statements, derived from Round 2 of the study, was reviewed to check if all experts still agreed with the statements. In addition, participants' written commentary was used to provide further explanation and context for the importance of the statements selected.

Review of the key elements of effective programming

The ranking patterns for important program elements were cross-checked against participant comments to see if all program features presented in the findings at this final round of the study were still viewed as important by all participants. The commentary provided verification of agreement with, and further explanation of, the 10 key program elements identified.

Round 3 Results

The confirmatory findings emerging from Survey 3 are presented below. Comments made about each statement are summarized and a final consensus list of 6 statements is presented.

Webinar commentary

Participants raised 2 main discussion themes during the webinar: the relationship between community, interdisciplinarity, and real-world connection; and the 'westernization' of STEM education. Regarding the community/interdisciplinarity/real-world connection relationship, one participant reinforced the notion that the learners' concerns, interests, and social context are the starting points when program planning but, for every learner, the desire is to expand their understandings of STEM beyond their immediate concerns into areas of broader/national/global perspectives. This discussion point served as a springboard for a discussion about whose version of STEM is actually being taught. The conversation about westernized

STEM curricula frequently invoked Indigenous ways of knowing to illustrate contrasting ways in which individuals learn and the sociohistorical perspectives that inhabit different knowledge systems. Participants engaged in an animated exchange about the "value-based ecosystem" of formal STEM education and how learners of different backgrounds may connect in different ways to the ways in which STEM subjects are presented in school. Participants spoke about the need to unlearn the idea of STEM neutrality, but there was some gentle push-back exerted by some participants who expressed a preference to move forward from today, rather than being concerned about colonial histories and the suggested threat of Eurocentric traditions.

Review of consensus statements

A summary of participants' written commentary on each of the Round 2 consensus statements is presented below. Reasons for inclusion or exclusion of statements in the final consensus list for the study are also detailed.

Bridging and access programs are needed because if students get low grades at any point in their formal STEM education, pathways for continuing their education and potential for STEM employment quickly close

Participants referred to a "leaky pipeline" for learners from families of low-income status, girls and people from "visible minority" groups that do not see themselves represented in extra-curricular STEM classes; experts emphasized the need to keep opportunities open for re-entry into STEM education throughout the formal education system. One participant emphasized that learners need to know people (e.g., family members, peers, and role models) who will support their interest in STEM education. In addition, another participant stated that the bridging programs need to be made relevant to the learner cohort so that the learners can see themselves reflected in the STEM they are learning. A prejudicial stance of some educators against learners from marginalized groups was also identified as a reason why bridging programs may be needed. The point was also made that there is a lack of connection to digital technologies and data-based STEM that drives much of the recent innovation in STEM careers. Points of disagreement with this statement suggested that participation in STEM careers is no longer so closely tied to school grades; it is really just the high school curriculum structure (particularly in mathematics), higher education, and the more traditional science career paths that are pushing the grade emphasis. In terms of consensus, the latter part of this statement would be removed because participants clarified that grades were not the only reasons why bridging and access supports are needed. One participant disagreed with this statement in this round of the study without providing explanation, so this statement was removed from the consensus list.

Curricula based on traditional subject divisions and grade structures limit the effectiveness of STEM education

Comments made by participants emphasized the need for connected, interdisciplinary thinking in contemporary society and modern careers. More than once, the experts emphasized the artificial/inauthentic nature of subject divisions. One participant referred to a disconnect between the Industrial Revolution legacy that remains embedded in the formal educational structure and our current Information Revolution era. Many participants called for more holistic ways of viewing knowledge and learning that might more effectively reflect how people operate in society. The notion of 'doing' more STEM rather than just learning about it was also presented by one of the experts. One participant totally disagreed with the statement, citing successes that have been gained with the subject and grade conventions that currently exist; other participants somewhat agreed, suggesting that it is difficult to conceive of an alternative to grading and that focused learning of subject matter is needed for depth of "knowledge acquisition" or as a "starting point". This statement was removed from the consensus list.

Educators have been increasing their capacity with respect to use of digital technologies

There was full agreement with this statement, but a clear distinction was made between educators learning how to connect with learners through digital technology and using the technology to enhance pedagogy. It was explained that this change was a necessary adaptation to the pandemic situation but there is still a long way to go if educators are to utilize digital literacy and technologies in their curriculum planning. Participants stated that there is still a lot of training needed if STEM educators are expected to use the technology "in a meaningful way that increases the quality of the learning experience" rather than just to enhance communication capacity. Participants identified the polarizing effect of the recent inclusion of coding into the K-8 curriculum. To align with the directive format of the other statements in the consensus list, this statement was reworded to ***Educators need to continue building their capacity with respect to the use of digital technologies, as demonstrated in response to the COVID-19 pandemic.***

Educators need to recognise and be held accountable for prejudicial behaviours (such as racism and sexism)

There was strong agreement from all regarding this statement, many seeing this as a basic tenet of any program for any learner. The experts spoke extensively about implicit biases and the importance of drawing these to the attention of educators so that learners are free to make decisions about their STEM interests and level of engagement without educators overlaying their own prejudices. Participants identified teacher education programs as locations from which this confrontation should start in a way that acknowledges the powerful, influential position from which educators speak and the long-term effects of educators who plant and reinforce limiting beliefs in the learner. The need for educators to be learners themselves was reinforced repeatedly, such that behaviours are constantly being checked and corrected. One participant reinforced the notion that accountability has to be extended to the learners as well so that there is an overall culture of correcting prejudice when it is revealed. This correction is not to serve as a way to "cancel people", it should be part of a community of learning about each other and growing together; the person exhibiting prejudicial behaviour needs to be willing to learn and work towards change. The suggestion was made that matters of "equity, diversity, inclusion and accessibility" need to be features of ongoing, reflexive professional development for all educators at all levels since everyone has blind spots that need to be addressed. Attention to these behaviours was described by one participant as being part of an educator's responsibility to care for the wellbeing of learners.

Program evaluation feedback should come from learners, educators, and family/community members

Comments about gathering evaluation data for programs pointed to the need for a breadth of feedback: "it isn't enough to get feedback from a single source anymore". The feedback needs to be acted upon by educators to make program improvements. Participants suggested that additional evidence of program efficacy should come from program designers and peer STEM education providers. They also proposed that other important learner data includes performance in competitions, post-secondary enrollment, and employment access. One participant suggested that the most important feedback is that which gets at areas of understanding that the program values but which the program cannot directly assess; when seeking evaluation feedback, program leaders should solicit input from those with unique perspectives on the learner, as well as from the learner themselves. Participants stated that connecting with the learner's broader community to gain feedback will also promote a sharing of responsibility for impacting the learner's engagement with STEM learning. One expert indicated that gaining feedback from multiple sources can also help the program leaders to identify areas of "disconnect" between educators and other members of the learner's community.

Reform to teacher education and providing good quality teaching resources are fundamental aspects of increasing the engagement of marginalized youth

Although there was universal agreement with this statement, there was acknowledgement that no resource should be seen as "grab-and-go" and that an educator's adaptability is vital if the aim is to reach all learners. Once educators have seen good examples of culturally responsive pedagogy, they should be encouraged and supported to adapt their own resources for the learners they encounter. The suggestion was made that good quality resources should be effective for all students so that marginalization is not created. One participant also suggested that educators will need to unlearn some things they have taken for granted. Participants stated that resources will only be made relevant to the lives of learners as educators are supported in "treating students like humans and individualizing their teaching"; this comes back to the notion of educators being willing and continuous learners.

Representation matters: learners need to see mentors and role models who indicate that achievement is possible for people from their sociocultural background

Participants agreed that part of an educator's role is mentorship. The key component of mentorship was described as an ability to connect with learners, not necessarily because of any overt sociocultural similarity (although this can help for many learners). One participant questioned why role models are expected in sports and the arts but not in STEM. Participants explained that there is a paucity of role models from certain demographic groups; this situation makes it all the more important that educators provide conditions that allow learners to develop a sense of belonging so that they can open up about experiences as well as challenges. Participants explained that mentors who share sociocultural backgrounds with learners are able to more readily discern if materials are relevant and can connect learning to "real world' contexts in meaningful ways.

The digital technology divide became more obvious during the pandemic

Although it was commonly agreed that the pandemic revealed a very uneven distribution of digital technology devices among learners, participants also stated that Internet availability was a major concern for programming. The lack of learner access to stable Wi-Fi provision was sometimes an issue of geography, rather than economics, since rural areas were often described as having patchy Internet service. More than one participant had mixed feelings about this statement, suggesting that discrepancies in access were already very obvious before the pandemic. One participant suggested that the difference in digital technology access was fundamentally a matter of parental prioritization. Due to the variance in commentary for this statement, it was removed from the consensus list.

There need to be more people from STEM marginalized backgrounds in leadership positions

Agreement with this statement was based on arguments about role models and representation described above. Many participants indicated that leadership roles are necessary but not sufficient to resolve deep-seated issues of representation. As described by one participant, educators need to “start valuing the contributions of people from marginalized backgrounds” irrespective of their hierarchical positioning. Another participant made it clear that these positions of leadership should not be tokenistic, rather it should be clear that they are based on merit and are taken up by well qualified, “equity-deserving” educators. Participants emphasized that there will be a sufficiently diverse set of leadership candidates when educators connect with and encourage learners to realize their STEM leadership potential. The value of the added diversity in leadership was described as providing “perspectives and viewpoints to organizations”, so broadening the knowledge base of people from non-marginalized groups.

Finalized list of consensus statements (in alphabetical order)

- Educators need to continue building their capacity with respect to the use of digital technologies, as demonstrated in response to the COVID-19 pandemic
- Educators need to recognise and be held accountable for prejudicial behaviours (such as racism and sexism)
- Program evaluation feedback should come from learners, educators, and family/community members
- Reform to teacher education and providing good quality teaching resources are fundamental aspects of increasing the engagement of marginalized youth
- Representation matters: learners need to see mentors and role models who indicate that achievement is possible for people from their sociocultural background
- There need to be more people from STEM marginalized backgrounds in leadership positions

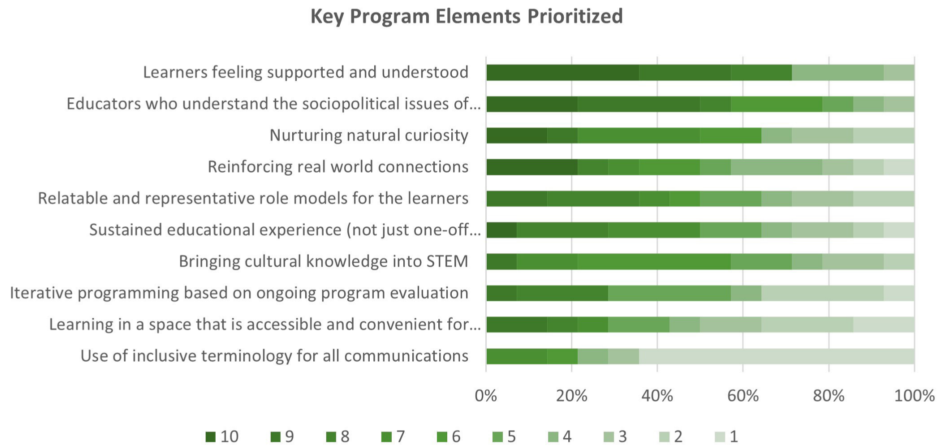
Prioritized program elements (in order of importance)

Participants offered very little commentary to explain their ranking of the 10 key program elements that emerged from Round 2 of the study. However, participants agreed that all 10 elements were important and that the overall ranking was extremely difficult. The final ranking pattern (from greatest to least important) is presented below:

1. Learners feeling supported and understood
2. Educators who understand the sociopolitical issues of marginalization
3. Nurturing natural curiosity
4. Reinforcing real world connections
5. Relatable and representative role models for the learners
6. Sustained educational experience (not just one-off workshops)
7. Bringing cultural knowledge into STEM
8. Iterative programming based on ongoing program evaluation
9. Learning in a space that is accessible and convenient for the learner
10. Use of inclusive terminology for all communications

The ranking pattern is summarized in Figure 20.

Figure 20. Participant ranking of key program elements.



Two program elements maintained their 'top 5' prioritization status in the Survey 3 ranking and the Survey 2 rating. These were ***Learners feeling supported and understood*** and ***Reinforcing real world connections***. These 2 elements overlap with one of the key discussion points during the webinar session. The program recommendation of ***Educators who understand the sociopolitical issues of marginalization*** was polarizing; it had the second highest mean ranking (of 7.4 out of 10) and the second highest median (of 8.5 out of 10) but, as revealed in the webinar discussion and elsewhere in the survey, exploration of sociopolitical issues is not always embraced in the context of STEM education.

Conclusions

Each organization will likely take something different from this study due to the range of program formats and learner groups served by the various organizations. Nevertheless, in this report we have focused on areas of consensus in participant responses and have derived a set of priorities and practices that are shared by STEM educators working with marginalized children and youth in the Greater Toronto Area. We anticipate that each organization will use the list of priorities and practices to enhance their program goals, professional learning foci, and hiring protocols for future program cycles so that they can continue their response to issues of STEM marginalization in ways that are locally relevant, and research informed.

As researchers, we were encouraged, but not surprised, by the observation that the experts consulted in this study were conversant in much of the recent research literature and had formulated some strong opinions on many of the contemporary equity-related issues facing STEM education. These experts seemed keen to continue their own learning and were humble enough to admit where the gaps in their own learning might be. By participating in the study, a number of the experts articulated their desires to continue the process of developing in their own understanding and, as such, they illustrate important characteristics of inclusive educators, acknowledging that when it comes to complex issues of social concern, educator knowledge is never complete.

When reflecting on the consensus statements generated through this study, it may seem that these are areas of common agreement in the field of education, but the participants in this study have shown that prioritization of these concepts during curriculum planning is often neglected due to focus on the 'stuff' of education, the knowledge nuggets that learners are expected to take away from an educational experience. By opting away from prioritizing specific topics and knowledge content, the experts have suggested an approach to curriculum planning that centres on the learning conditions and foundational philosophical underpinnings before focusing on the curriculum content. The consensus statements, along with the list of program priorities, can be used in program planning to generate goals that articulate the perspectives that an organization wants to promote as well as those that it would want to combat.

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