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Co-creating an inclusive science, technology, engineering, and mathematics program: a gender-responsive approach

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ABSTRACT

Gender parity in education has improved in many countries alongside global and local efforts to promote gender equity. However, in Malaysia, male participation in related fields, especially science, technology, engineering, and mathematics (STEM), is increasingly at risk due to a subtle trend of a reversed gender parity index. This qualitative research aims to examine what makes up an inclusive STEM program, with specific foci on curriculum co-creation and gender responsiveness. Through purposive sampling of various stakeholders (n=47), several rounds of focus group discussions and interviews were conducted. Thematic analysis revealed key components of an inclusive STEM program, and strategies for promoting gender-responsiveness when co-creating this program. Moreover, these findings highlight the importance of enhancing students' engagement in STEM through participatory decision-making and tailored interventions. The research contributes to both theory and practice by making recommendations for developing more inclusive, gender-responsive learning environments in STEM education.

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1. INTRODUCTION

Inclusive education is the practice of providing meaningful and equitable learning experiences for all students, regardless of ability or background, in mainstream educational environments [1]. This approach aims to promote diversity and overcome learning barriers, resulting in a supportive environment in which all students can succeed. Inclusive education in the context of science, technology, engineering, and mathematics (STEM) extends beyond providing access as it also focuses on creating environments where every student feels valued, supported, and empowered to engage meaningfully in STEM learning. In other words, inclusive STEM education embraces diversity and eliminating discrimination to foster quality education for all students [2].

According to UNESCO [3], gender-responsive instruction acknowledges the distinct needs and experiences of students of different genders. Gender-responsive instruction is an educational approach that recognizes students having different learning needs and experiences based on their gender [4]. It involves raising awareness among educators about how gender influences learning styles and classroom dynamics. This approach promotes equitable participation by encouraging all students to engage actively and present their diverse perspectives, while also creating a safe learning environment free from gender-based discrimination [5]. Within STEM, Chan discussed the significance of gender and how it can have a large

impact on students' academic performance and desire to work in relevant fields [6]. Similarly, Kricorian *et al*. [7] emphasized the importance of students to interact and receive mentoring in STEM classrooms by those of the same gender as it can significantly increase the likelihood that the students pursue relevant careers. Other studies also found that gender-responsive instruction improves students' attitudes, interest and motivation in learning STEM [8]–[13]. Therefore, adopting gender-responsive instruction is an appropriate step in the direction of enhancing the inclusivity and the quality of STEM education.

Meanwhile, curriculum co-creation is becoming more widely known as a pedagogical method that increases student engagement through a democratic learning environment [14]. Key qualities of curriculum co-creation include shared goals, decision-making, negotiating, mutual respect, and reciprocity [15]. According to Lubicz-Nawrocka and Bovill [16], curriculum co-creation effectively fosters student ownership and participation in teaching and learning, which in turn increases students' satisfaction of their education. Following this, curriculum co-creation harnesses a potential to be an effective strategy for ensuring access to high-quality, inclusive education for all [17], [18]. Curriculum co-creation can be effectively used to foster an inclusive learning environment through several approaches. First, curriculum co-creation enhances engagement and motivation by involving learners directly in designing their learning experiences. This participatory approach allows students to voice their interests, preferences, and learning goals, fostering a sense of ownership and responsibility for their education. Second, co-creation promotes deeper learning as students collaborate with their peers and educators to co-construct knowledge. This active involvement not only increases the relevance and applicability of the curriculum to their lives but also develops critical thinking, problem-solving, and communication skills essential for professional success. Overall, curriculum co-creation gives students greater autonomy over how they direct their individual learning while also encouraging a more collective mindset as they remain aware of their choice that could impact the group's overall learning.

Building on the growing field of gender-responsive instruction and curriculum co-creation, this research places a focus on framing an inclusive STEM program through the integration of these two concepts. This research argues that both gender-responsive and curriculum co-creation concepts can help address gender disparities in STEM education which then contributes to achieving inclusive and quality education. This qualitative research aims to investigate the key components of an inclusive STEM program, with a specific focus on strategies for ensuring gender responsiveness. The research questions are as follows:

- What are the key components of an inclusive STEM program?
- What are the strategies for promoting gender-responsiveness when co-creating this program?

Over the past two decades, Malaysia has achieved gender parity in education, effectively eliminating disparities in access, retention, and educational outcomes. Malaysian girls have consistently outperformed boys in academic achievement since 2007, with the latest Organisation for Economic Co-operation and Development (OECD), Programme for International Student Assessment (PISA) 2022 results showing that girls scored 10 points higher than boys in mathematics. Moreover, boys represent a higher percentage of low performers in mathematics, with 63% of boys falling into this category compared to 55% of girls. In terms of access, the gender parity index (GPI) continues to rise, with girls benefiting from increased access at all educational levels-primary, secondary, and tertiary. For example, in 2019, the gross enrolment rate for girls in secondary schools (87%) was higher than that of boys (80.7%). Girls also exhibit better school retention, missing fewer school days and staying in school longer, with a school life expectancy of 13.44 years for girls compared to 12.46 years for boys.

Despite these advances, challenges remain. The Ministry of Education Malaysia (MOE) reports a low level of male participation in science education, with fewer than half of the students in all science-related subjects being male [19]. This highlights the need to address the issue of gender disparity in STEM fields, particularly in light of the "lost boys syndrome". This syndrome reflects how boys, especially those from disadvantaged backgrounds, are increasingly falling behind in education due to a range of challenges. Such factors include the pressure to help support their families financially or struggles with behavioral issues at schools [20], [21]. These factors, coupled with a lack of male role models and tailored educational support, may also contribute to this syndrome [22]. Although STEM education in Malaysia has achieved gender parity, this research implies that male STEM graduates have been hired at higher rates than those who are female, indicating that gender equity in the workforce has not yet been reached. Given these statistics, it is crucial to explore how STEM education can become more inclusive, especially by addressing gender disparities through innovative approaches such as curriculum co-creation. The novelty of this research is its focus on gender-responsiveness in co-creating STEM programs. Specifically, this research addresses the emerging issue of the "lost boys syndrome" in Malaysia. This research also provides practical insights into how participatory decision-making can foster more inclusive and engaging STEM learning environments for both female and male students.

2. METHOD

This research employed a qualitative research design to explore the components of an inclusive STEM program, emphasizing gender responsiveness and curriculum co-creation. This STEM program was conducted for two years where it aimed to enhance inclusivity through curriculum co-creation and gender-responsive instruction. The program was developed in three stages, namely pre-assembly, design and revision. This paper specifically reports on the findings from the pre-assembly stage, which was targeted at achieving consensus among stakeholders on how to make STEM program inclusive. The decision to focus on these findings allows for a more detailed analysis, while the other stages are still ongoing and will be explored in future papers.

During the pre-assembly stage, the researchers gathered perspectives from different stakeholders including STEM experts, curriculum developers, gender specialists, industry representatives, school leaders, teachers, and students. Industry representatives here refer to professionals or experts from companies, organizations, or institutions directly connected to STEM fields. All potential participants were asked to give informed consent, and 60 agreed to take part in the research. However, only 47 of these participants met all three established criteria, namely a demonstrated interest in STEM fields, active involvement in gender equity initiatives within STEM, and the ability to commit to the research. Table 1 provides a brief description of selected participants.

Next, all participants were assigned to focus group discussions, while some participants were further interviewed to seek deeper understanding of their perspectives. Seven focus group discussions and ten interviews were conducted using an interview guide that was developed to achieve the research objectives. Among the topics covered in the interview guide are the definition of inclusive education, gender issues, challenges of inclusive STEM education, and strategies to support gender-responsiveness in STEM. Given the semi-structured nature of both the interviews and the discussions, the participants attained complete autonomy to voice their points of view. Both focus group discussions and interviews were conducted face-to-face in English, audio-recorded, and lasted an average of more than thirty minutes [23], [24].

For data analysis, a step-by-step thematic analysis approach was systematically designed and undertaken. First, the tape recordings were repeatedly listened before being manually transcribed. Second, the transcripts were analysed to find common patterns or unique findings. Third, themes were generated by constantly comparing them within and across the transcripts. Several strategies were implemented to assure the trustworthiness of the entire research such as participant checking method, triangulation and audit trail [25].

Table 1. Description of selected participants

Participant	Gender	Professional roles	Organization
P1	Male	University lecturer	Government
P2	Female	School teacher	Government
P3	Female	Scientist	Industry
P4	Male	School teacher	Government
P5	Female	Gender specialist	Government
P6	Female	College principal	Private
P7	Male	Education officer	Government

3. RESULTS AND DISCUSSION

Thematic analysis revealed four themes corresponding to the research questions. Each research question is addressed by two themes. Table 2 presents the themes emerged in this research.

Table 2. Themes

Research questions	Themes
What are the key components of an inclusive STEM program?	Theme 1: mutual understanding of 'inclusive' Theme 2: students remain the core of inclusive teaching and learning
What are the strategies for promoting gender-responsiveness when co-creating this program?	Theme 3: building a stable educator-learner dynamic Theme 4: integrating gender-responsive learning support and environment for effective student outcomes

3.1. Theme 1: mutual understanding of 'inclusive'

The first theme describes the importance of reaching an agreement on what constitutes inclusive STEM education. The participants explained that what educators understood about inclusive teaching and learning might differ from what the students perceived. For example, the participants pointed out that

educators usually interpreted 'inclusive' as giving minority, special needs, and displaced student's equal access. While other participants noted that educators tend to not view gender as an important component of the 'inclusive' concepts. Thus, these participants elaborated on the need to highlight gender as part of inclusive STEM education.

> *"Before starting, we need to ensure that we start on the right foot, meaning that we have to agree to what inclusive is… Gender is essential part of inclusive."* [P26L15-19]
> *"Years ago, while I was still a student teacher, I do not really get the exposure of teaching in response to females or males. I do not really get how gender and inclusive relates to one another. However, in recent years, I start learning that boys and girls understand differently. Thus, if we are talking about inclusive, other than races, gender should be considered as well."* [P4L7-12]

Furthermore, participants emphasised socio-cultural understanding of inclusive STEM education. From a gender perspective, they discussed how mainstream commonly communicates gender as beyond females and males and how it can include non-binaries. According to them, such mainstream understanding was totally unacceptable and against the socio-cultural norms here in Malaysia. As a result, both educators and students should reach a mutual understanding of 'inclusive' that is socio-culturally appropriate before proceeding into co-creating an inclusive STEM education.

> *"School teachers are responsible to provide education that is in line with local cultural norms. We have to remember that students now have greater exposure due to social media and thus may be influenced by cultures that are not accepted here. We need to reach a common ground here of what makes 'inclusive' in our own context."* [P31L20-25]

3.2. Theme 2: students remain the core of inclusive teaching and learning

The second theme emphasizes the need of placing students at the core of inclusive teaching and learning. However, the participants claimed that teachers were often preoccupied with getting other tasks done, such as finishing the syllabus on time and completing administrative works. As a result, the students' learning needs were often overlooked and not met during class. The idea of 'inclusive' should imply that both educators and learners understand that the latter have rich life experiences that can be applied to improve teaching and learning, and that they should be the foundation for each decision made during class.

> *"As an educator, I face time constraint to finish my lesson on time. I do admit that at times that is my only focus. And not the students."* [P13L6-8]

When discussing about gender, the participants highlighted that many educators lacked training in recognizing the varying learning needs across different genders. Consequently, educators employed a 'one-size-fits-all' approach to teaching STEM. They often used real-life examples that resonated more with their own experiences. Since most STEM teachers were female, the examples used to illustrate scientific concepts commonly reflected activities familiar to girls rather than boys. For instance, activities like using cooking to explain chemical reactions, gardening to teach plant biology, or knitting to show patterns in math are often more relatable to girls because of traditional roles that connect them to nurturing, creativity, and communication. Participants also agreed that curriculum co-creation could refocus attention on addressing students' individual learning needs, making the approach more inclusive and responsive to students' voices in the teaching and learning process.

> *"Sometimes, we have many things to manage and complete at one time, which somehow shift our focus away from our students. I do admit that I lack training to modify my teaching according to genders. Now that more short professional courses are touching on this way of teaching, I find it easier to practice gender-responsive teaching when I seek feedback or get my students' opinions during class."* [P2L25-29]

3.3. Theme 3: building a stable educator-learner dynamic

The third theme highlights building a stable educator-learner dynamic as one of the strategies to promote gender responsiveness when co-creating an inclusive STEM program. The participants explained that co-creation posed a challenge to the traditional role of educator as a knowledge transmitter, creating a conflict among them. This was because the educators were not comfortable providing autonomy to the students in directing their own teaching and learning. Moreover, some educators might feel hesitant to give students more control because they want to ensure the curriculum stays on track and that learning goals are met. In this way,

the educators' lack of trust can severely impede the co-creation process, and students' perspectives or opinions might be sidelined in the process. However, the participants argued that students can be given more autonomy by letting them suggest topics, set their own learning goals, or lead discussions with their peers.

> *"Relationship and dynamic are critical in any co-creation process. But it is most important considering that if teachers are not inviting enough, students may just stray away from co-creating. So, any form of student inclusion is lacking."* [P42L29-33]

According to the participants, there were many strategies for building a stable educator-learner dynamic. They stated that the process should start with educators recognizing the value of the diverse experiences, ideas, and perspectives that students bring to the learning environment. Educators should clearly communicate the roles and responsibilities related to co-creation to each student. Additionally, providing dedicated space and time for every student to share their opinions ensures that all students, regardless of gender, have equal opportunities to contribute.

> *"There are many ways that I tried to build a stronger relationship with my students. I genuinely show my concern over their success, my interest in their daily lives and I would try my best to relate to them. Co-creation itself is tough on us and the students, so as an educator, I need to make sure that my students are comfortable in sharing their ideas and thoughts."* [P17L32-37]

3.4. Theme 4: integrating gender-responsive learning support and environment for effective student outcomes

The fourth theme features integrating gender-responsive learning support and environment for effective student outcomes. The participants stressed that the availability and effectiveness of learning support that is gender-responsive should go hand-in-hand with the development of a learning environment that supports students' growth across academic, emotional, and psychologically dimensions. This integrated approach not only fosters a meaningful educational experience but also ensures that all students have the tools and support needed to reach their full potential. They illustrated the importance of personalized learning support strategies that targeted at addressing individual student needs through close educator-student interactions, learning style assessments and background surveys.

> *"Without good learning support, the learning environment cannot support the students. Without a good learning environment, teachers may not be able to carry out learning supports effectively… Both should go hand-in-hand."* [P22L23-27]

Furthermore, some participants noted that traditional STEM classrooms often create an invisible, 'threatening' environment where students anticipate seriousness, boredom, and immense pressure to excel in exams. The participants elaborated that adopting curriculum co-creation allows learners to engage in a more relaxed, welcoming, and non-threatening environment, where they could discuss gender topics comfortably. This approach also facilitates the exchange of ideas that are more relevant to the students, enhancing mutual understanding among the girls and boys. Additionally, the educators could benefit from this exchange by gaining insights that are interesting and important from the students.

> *"It is very common to hear how boring a science class is, probably because of the old, conventional lecturing method. Curriculum co-creation is a complete opposite of it that sparks students' curiosity and challenges them. The students can play around with their ideas under guidance of the teachers. They can discuss with one another and see how they all understand things in a different way, so that creates a mutual understanding among the students as well as the teachers."* [P36L34-40]

3.5. Discussion

This research makes convincing arguments that integrating gender-responsive instruction and curriculum co-creation can assist in the design of an inclusive STEM program. The findings show that developing a mutual understanding of what 'inclusive' implies is one of the most important aspects of what makes a STEM program inclusive. This result is consistent with Orozco and Moriña's [26] assertion that it is critical to understand the meaning that the term 'inclusive' conveys. The prominence of a socio-culturally appropriate understanding of 'inclusive' is unique to this finding, differentiating it from other definitions of 'inclusive'. Here, an inclusive STEM program is expected to meet the traditional expectations of gender, roles, and diversity that fit into the sociocultural norms. Without perpetuating a limited understanding of the

concept of inclusivity, this research argues that in our local context, traditional gender roles are deeply rooted in cultural and religious practices. In this case, defining gender inclusivity in education should align with these long-standing norms in the country, where gender identities closely relate to the established cultural and religious frameworks. In line with UNESCO [27], this approach helps maintain social cohesion and prevents potential conflict or disruption that might arise from challenging deeply ingrained gender structures. However, more studies found that while there is a significant presence of traditional gender norms, there are also emerging attitudes that challenge these norms, particularly among younger generations [28]. This dynamic shift leads to the next key component of what makes a STEM program inclusive reported by this research, which is placing students at the core of inclusive teaching and learning. As previously discussed, as gender norms and roles are shifting in these modern days, meeting students' learning needs has become more complicated for educators. Curriculum co-creation provides a space and opportunity where students can voice out their learning needs, making it easier for teachers to identify and respond accordingly [29]. For instance, in a traditional STEM classroom, a boy may feel uncomfortable asking the teacher more questions or seeking clarification because he struggles to relate to the female-oriented examples the teacher gave. However, during curriculum co-creation, the boy can freely and publicly express his opinions without fear of examination or interference with class instruction.

Moreover, there are several strategies for promoting gender-responsiveness when co-creating this program. First, it is important to build a stable educator-learner dynamic to encourage students' participation in making decisions about their learning. Similarly, strong relationships between educator and learners play a critical role to help students feel more comfortable in co-creation [30]. Since most students are accustomed to the traditional STEM class where students are the passive recipient of knowledge, the curriculum co-creation approach will definitely pose a challenge for them to comfortably and respectfully share their opinions, ideas and experiences regardless of their genders. Additionally, curriculum co-creation requires a transformation on behalf of the educators as they have to share the responsibilities in deciding critical aspects of teaching and learning [31]. The educators also need to be aware of the importance of including each students' voice and further prompt any discussion to facilitate a better understanding among the students. Second, this research found that integrating gender-responsive learning support and environment can promote gender-responsiveness for an inclusive STEM program. This way educators should provide learning support and foster a learning environment that allows gender to be discussed more openly and comfortably [32]. Both of these components should be complementary to ensure a cohesive and effective educational experience. When both are aligned, they work together to address students' academic, emotional, and psychological needs, enhancing engagement and overall outcomes.

4. CONCLUSION

This research has highlighted the importance of integrating gender-responsive instruction and curriculum co-creation in designing an inclusive STEM program. The findings underscore that a shared understanding of what constitutes 'inclusivity' is particularly essential for establishing an inclusive educational environment. Notably, this research reveals that the concept of gender presents both challenges and opportunities due to direct influence of traditional gender norms and contemporary shifts in attitudes towards gender, especially among younger generations. These shifts urgently call for a student-centered approach to teaching and learning, with curriculum co-creation as a key tool. This approach which actively involved the students in expressing their concerns and sharing their ideas in developing the curriculum creates an engaging as well as responsive learning environment. Strategies identified through this research could potentially be used to support a positive educator-learner relationship that is essential for student's participation and ensuring that all voices are heard. Most importantly, this relational dynamic helps students transition from passive recipients of knowledge to active contributors in their educational journey. Thus, this research provides valuable insights and recommendations for developing inclusive STEM programs that cater to all students' needs while promoting equity and enhancing overall educational outcomes. The study's limitations include a small sample size, which may limit the generalizability of the findings, as well as its focus on a specific regional context, which may not reflect broader educational settings. Some challenges in integrating gender-responsive instruction and curriculum co-creation in STEM programs is overcoming resistance from educators and administrators who may be unfamiliar with such approaches. Additional challenges include ensuring adequate resources and training to support these initiatives effectively. Future studies may evaluate the long-term effectiveness of gender-responsive, co-created STEM programs by tracking student outcomes such as academic achievement, motivation and career choice.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
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CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this research.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' equivalent institutional committee.

DATA AVAILABILITY

The data that support the findings of this research are available on request from the corresponding author, [NMN]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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