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# ASSESSING TEACHER-LECTURER COMPETENCY IN SCIENCE, TECHNOLOGY, ENGINEERING, ARTS, AND MATHEMATICS (STEAM) IN KWAZULU-NATAL

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## ABSTRACT
The convergence of technology and digital communications has revolutionized most businesses, including education and training facilities. Advances in technology has completely transformed the world of work. Being well-educated is no longer sufficient. What matters is the possession of critical essential talents, skill sets, and capabilities. South Africa is characterised by high inequality, poverty and high unemployment. Thus, provision of quality education is one of strategies that could be employed to address such developmental challenges. Hence, the objective of this study was to assess teacher-lecturer competency in Science, Technology, Engineering, Arts, and Mathematics (STEAM) in KwaZulu-Natal. This study was conducted in different parts of KwaZulu-Natal province with participants from various schools and institutions of higher learning. The study was commissioned due to skills deficit that is perpetrated by, amongst other things, the poorly functioning basic education system, inadequate infrastructure, shortage of STEAM teacher supply, and skills mismatch. The study employed an exploratory research design, and the survey was used as the research strategy.  Among other findings, the study found that while a significant portion of educators expressed a commitment to promoting reflective and critical thinking among learners and students, inadequate STEAM equipment and infrastructure continued to be the primary challenge in implementing STEAM. Furthermore, the study found that there is a majority support for the STEAM centres which suggests a positive inclination towards their establishment, underlining the perceived value they could bring to the educational landscape for both teachers and students. This study recommends a targeted professional development programs for educators at primary and secondary schools. In addition, this study advocates for interdisciplinary collaboration among educators in primary and secondary schools which must be pioneered by the department of education. It was further recommended that knowledge exchange and knowledge transfer be facilitated, and specialized training in the development and use of technology, software, and other teaching materials for educators in primary and secondary schools be provided.

**Keywords:** Science, Technology, Engineering, Arts, Mathematics, Education, Skills.

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## 1. INTRODUCTION

The advancement of technological innovation, as expressed in automation and digital transformation are amongst the key symbols and drivers of revolution in the education, skills production, and employment [1]. This revolution has implications for society and industry, in that they must find ways of proactively aligning to the contemporary demand and supply of skills to achieve sustainable human development and resilient economic growth [2]. In the 21st century, there is a rapid advancement in technology which requires innovative, analytic, critical, and digital skills. As a result, the demand for professional and associate professional occupations in the Science, Technology, Engineering, Arts and Mathematics (STEAM) field is projected to grow significantly from 2015-2025, with anticipated increases of 13% and 7%, respectively, while all occupations are expected to experience only a 3% increase in employment [1].

There are two primary pedagogical approaches that strive to promote effective science teaching and learning. These approaches are STEM (Science, Technology, Engineering, and Mathematics) education and STEAM (Science, Technology, Engineering, Arts, and Mathematics) education [3]. Scholars note that there is no consensus on the exact definition of STEM education [2], however, various scholars from different fields have made attempts to define and conceptualise STEM education. For example, [4] defines STEM education as an approach that supports student participation using engineering and technology and improves students' learning in science and mathematics. On the other hand, Israel, [5] argues that STEM education should be understood beyond the contexts of four STEM domains (Science, Technology, Engineering, and Mathematics). In general, STEM can be looked at as a multidisciplinary approach to teaching and learning that seeks to prepare competent students at all levels with the skills in the rapidly expanding scientific society. It seeks to provide opportunities for students to be able to solve problems, to be innovators, inventors, self-confident, logical thinkers, and technologically literate [5, 6].

In the global context, the rise of industrial need for technology and the requirements of the labour market, thus access to quality STEM education is essential for meaningful careers. On the basis that the STEM approach makes a holistic education (connects to learner's real-life experiences), it has been recognized as the main competence source especially for scientists, engineers, and technicians [1].

In today's fast-paced world, the demand for digital and critical skills presents a challenge to the new generation of innovators in that, they need exposure to interdisciplinary teaching and learning, which will enable them to create sustainable solutions. What is also evident is that STEM skills are in demand and has potential to give students the edge to flourish in any chosen career [1]. STEM education and training doesn't only seek to develop experience and capability in each individual field, but also to develop ability to work across disciplines and generate new knowledge, ideas, and products through inter-disciplinary learning [7].

Although STEM initiatives are increasing globally, challenges related to supplying quality education in these disciplines are still persistent [2]. Compared to other countries in the Southern African Development Community, South Africa has the potential to develop and implement STEM education and skills due to its middle-income status [2]. However, efforts are constrained by systematic challenges [2]. Literature shows that inadequate school infrastructure, a shortage of STEM-skilled teachers, poor education system exacerbated by poverty are major constraints to providing and accessing quality STEM education in South Africa [2, 8-10]. Consequently, there are low numbers of students motivated to pursue STEM-related careers [8], threatening the country's capacity to eliminate poverty, inequality, and unemployment. This has prompted calls to change how science subjects are taught in the classroom by integrating arts into STEM learning.

Several scholars have found that there has been an increase in the body of literature criticising the lack of the arts field in STEM [11-14], arguing that the "arts" is useful for both educational and economic development [3]. While STEM is good, especially on focusing on scientific concepts, STE(A)M education grew out of STEM education, where (A) represents fields, such as liberal arts, language arts, social studies, physical arts, fine arts, which ignites imagination, and creativity [3]. The labour market is demanding more creative and human skills including social and emotional intelligence to be able to solve problems holistically [4, 11, 15, 16]. Moreover, the need to change the narrative of how science is taught to enhance the learners' STEM performance and interest in pursuing STEM-related careers is crucial for future economic development. Therefore, the transition from STEM to STEAM education approach has been receiving attention from researchers, teachers, the Government, and policymakers over the past decades [7].

The integration of Arts in STEM education stimulates creative imagination within STEM learners which has been previously overlooked [7, 11, 17]. This allows for policy reform that places more emphasis on how STEM education is taught in the classroom [7]. Lev Vygotsky's theory on social development (1934) stresses the significance of integrating arts in learning STEM subjects from a young age [15]. According to Vygotsky, children's cognitive development occurs from experiences in challenging and engaging activities [15]. This theory reflects in several STEAM education research. [18]state that the integration of arts "benefits children's cognitive, emotional and intellectual development as well as their critical thinking and problem-solving skills".

South Africa developed a National Development Plan (NDP), with the main goal to eliminate poverty, inequality, and unemployment. The plan advocates for the creation of a capable and inclusive state, where all socially and economically excluded are integrated into the growth and development initiatives [19]. The plan also strives for the development of an environment where people will have the ability to improve the quality of their lives through education, health care, jobs, skills development, etc. In addition, government top priorities are articulated in New Growth Path (NGP), National Skills Development Strategy (NSDS) III. All with the aim to contribute to the enhancement of the goals of a developmental state through education and training. Amongst the top goals, is to produce adequate and skilled workforce, which will contribute to the empowerment of workers, especially women and the youth [19].

There are numerous challenges that hinder the implementation of STEAM in South Africa. These challenges include shortage of qualified teachers, poor infrastructure and learning facilities, limited access to updated learning material, teacher learner ration (overcrowding) etc. According to [17], in South Africa, four out of five teachers in public primary schools lack the content knowledge and pedagogical skills to teach mathematics. In a nationally representative sample of primary schools, 79% of Grade 6 Mathematics teachers failed to score 60% on a Grade 6 test. Like most provinces in the country, KwaZulu-Natal (KZN) suffers inequality, poverty and from high rate of unemployment which is perpetuated by outdated educational practices, skills mismatch, and skills shortage. According to the [17], high and persistent levels of unemployment, together with job vacancies that remain unfilled, are often attributed to mismatches between jobs and skills, thus going forward it is important that skills planning, and production is responsive to the anticipated skills need. Amongst the practical solutions to address skills mismatch in the labour market, is by increasing the number of STEAM educators in the education and training space. The sooner the STEAM education infrastructure is put in place, the sooner the positive alignment between skills

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demand and supply. There is recognition that teachers play a central role in learner development, the challenge has been lacking STEAM pedagogy training and subject matter competency required to improve the overall quality of education delivered by schools [20]. Therefore, the main objective of this study was to assess teacher-lecturer competency in Science, Technology, Engineering, Arts, and Mathematics (STEAM).

## 2. **METHOD & MATERIAL**

### 2.1 Research design

This study used a quantitative research approach to assess then competency of teacher- lecturer competency in STEAM. Quantitative research involves the collection of data so that information can be quantified and subjected to statistical treatment to support or refute "alternate knowledge claims" [21]. Quantitative research has various advantages, including bigger sample sizes and shorter data gathering times [21]

### 2.2 Target population

[22] posit that all researchers need to understand the population from which the study is drawn. Thus, the researcher needs a deeper understanding of the population dynamics to select a study sample that is fully representative. This is to ensure that only relevant participants are selected to mitigate the risk of non-response [22]. This study's target demographic consisted of STEAM teachers and lecturers from schools and universities throughout all 11 KwaZulu-Natal district municipalities. KwaZulu-Natal has roughly 29903 educators, including teachers and lecturers.

### 2.3 Sampling strategy

This study used non-probability sampling with the purposive sampling technique. This study employed a purposive sampling strategy, with the goal of allowing the researcher to include only "information-rich" participants who possessed significant insight and thorough knowledge of the subject under study. The total number of STEAM educators in KwaZulu-Natal (KZN), including both teachers and lecturers, is estimated to be 29903 [23]. This estimate is inclusive of 24 000 teachers, 5122 Technical and Vocational Education and Training (TVET) lecturers, and 431 university and university of technology lecturers. Using the Raosoft sample calculator to ensure a representative sample, the following sample sizes from this educator cohort were determined: 659 teachers; 588 TVET lecturers; and 262 university and university of technology academics. Consequently, the desired sample size was 1509, however only 966 respondents participated in this study due to resistance from academics to be subjected to STEAM competency assessment (highlighted under the limitations of the study). After data cleaning, after data cleaning to ensure the integrity and credibility of the data analysis was performed on 891 respondents.

### 2.4 Data collection strategy

This study employed a combination of self-administered online surveys and assisted-administered surveys. A structured questionnaire was developed to capture relevant information regarding the competencies of teacher-lecturers in the STEAM disciplines. The self-administered online surveys were distributed electronically to participants, allowing for convenient and independent responses. Moreover, for participants who required assistance or preferred a more interactive format, assisted-administered surveys were conducted with the support of trained personnel and telephonic interviews.

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### 2.5 Validity and Reliability

According to [24], it is critical that researchers verify measurement validity. This is described as the degree to which a data collection method(s) or instrument generates accurate conclusions, or measures what it is designed to measure [17, 24, 25]. In this study, a panel of experts was employed to validate the instrument (questionnaire) using content validity and cognitive interviews. The Item-Content Validity Index (I-CVI) was employed in this investigation [26]. Three academic content experts rated the relevance of each item on a 4-point Likert scale: 1 = not relevant, 2 = slightly relevant, 3 = relevant, and 4 = extremely relevant. The number of experts who scored 3 or 4 on each issue was then counted (3,4 - relevant; 1,2 - non-relevant). The recommended I-CVI ranges from 0.78 to 1.00. The I-CVI score that was obtained for this study was 0.9.
Reliability is concerned with whether the research can be replicated in terms of methodologies utilized and whether the same findings would emerge if the study were repeated [26]. Because there were multiple items measuring the same variable, the researcher employed Cronbach's coefficient alpha for reliability assessment [26]. Furthermore, research questionnaire was piloted prior to conducting the survey. The same research instruments were used for all respondents/participants in the study. Following data collection, the questionnaire was reviewed for accuracy and completeness. The study excluded responses that were returned incomplete.

### 2.6 Ethical considerations

Ethical considerations were carried out by obtaining written and signed informed consent from the research participants. The informed consent form provided a brief explanation about the purpose of the study, the nature and type of the information to be collected and rights of the participants. This included informing the respondents that participation was voluntary, and that confidentiality and anonymity would be ensured. Other ethical considerations that were considered in conducting this study included confidentiality, transparency, accountability, professionally among others. Research respondents participated freely without being coerced or compensated to do so. Additionally, Research Ethics Clearance was obtained prior to commissioning this research.

### 2.7 Data analysis

Research data was analysed descriptively using SPSS and visualised using MS Excel. The collected data underwent a data cleaning process, whereby all identified errors and duplications were removed. Descriptive statistical procedures in the form of frequencies were used to analyse the data to produce the expected outputs. The frequency tables with corresponding summary charts were produced using the STATA and Microsoft Excel as data analysis tools. Data collected in this study was stored on the secured data portal for safekeeping and future reference and was used for the purpose of this study only. The data will be kept for five years; thereafter, it will be disposed of by deleting it from the data portal system in accordance with the POPPI Act.

### 2.8 Exclusion criteria

Academics outside the STEAM discipline were intentionally excluded from participating in this study.

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### 2.9 Limitations of the study

Limitation of this study included inability to reach the targeted sample size of 1509. While it is not always possible to acquire the targeted sample size, it would have been ideal to reach it, as it provides more justification to generalize the findings to the entire population. During data collection it was observed that there was resistance from potential participants, citing that the department of Education uses a top- down approach in decision making. This approach does not consider the challenges faced by academics nor are they consulted in a decision-making process. There was also fear that the competency assessment would result in academics losing their jobs if they were determined to be inept.

## 3. RESULTS AND DISCUSSION

### 3.1 Socio-demographic characteristics of steam educators and lecturers

The analysis of socio-demographic characteristics among STEAM educators and lecturers reveals a diverse and dynamic landscape within the educational sector (Table 1). Participants were predominantly South African (96.30%), the sample showcases a blend of age groups, with a significant presence in the 25-54 years (24%) range, particularly concentrated between 35-44 (31%) and 45-54 years (30%). Female (53.87%) representation slightly surpasses males (45.90%), while other genders constitute a minimal percentage.

District-wise, certain areas like Umkhanyakude (19.36%), uMgungundlovu (16.17%), and eThekwini (12.76%) exhibit higher STEAM educator density. Educationally, most of the academics hold bachelor’s degrees or advanced diplomas (46.69%), with notable cohorts possessing honours or B Tech degrees (19.3%). Employment roles span a spectrum from entry-level (6.17%) to senior subject specialists (31.87%), reflecting a mix of experience and expertise. Encouragingly, a substantial proportion of educators have received STEAM content training (75.53%), underscoring the commitment to enhancing teaching quality in these disciplines. However, strategies must be put in place to adequate train STEAM teachers (24.5%) that have not been trained in STEAM content. This will ensure their competency in teaching these critical subjects. Garson's (2004) observation that only 15% of teachers were trained in STEM teaching aligns with international concerns regarding educator preparedness for the 4IR. Drawing parallels, a report by Dr. Rishagen Viranna highlights that, in 2015, 2,875 educators teaching STEM in KwaZulu-Natal were unqualified, mirroring challenges seen in other regions [27].

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**Table 1: Socio-demographic characteristics of STEAM educators and lecturers**

| Variables | Measures | Freq. | Percentage |
|---|---|---|---|
| *Citizenship* | Dual | 2 | 0.22 |
| | Non-South African | 31 | 3.48 |
| | South African | 858 | 96.30 |
| *Age* | 18-24 years | 38 | 4.26 |
| | 25-34 years | 214 | 24.02 |
| | 35-44 years | 272 | 30.53 |
| | 45-54 years | 269 | 30.19 |
| | 55-65 years | 95 | 10.66 |
| | Above 65 | 3 | 0.34 |
| *Gender* | Female | 480 | 53.87 |
| | Male | 409 | 45.90 |
| | Other | 2 | 0.23 |
| *District Municipality* | Amajuba | 55 | 6.26 |
| | Harry Gwala | 33 | 3.76 |
| | King Cetshwayo | 35 | 3.99 |
| | Ugu | 146 | 16.63 |
| | Umkhanyakude | 170 | 19.36 |
| | Umzinyathi | 20 | 2.28 |
| | Uthukela | 63 | 7.18 |
| | Zululand | 74 | 8.43 |
| | eThekwini | 112 | 12.76 |
| | iLembe | 28 | 3.19 |
| | uMgungundlovu | 142 | 16.17 |
| *Level of education* | Bachelor's degree /Advanced Diploma | 416 | 46.69 |
| | Diploma / Advanced Certificate | 149 | 16.72 |
| | Doctoral degree | 36 | 4.04 |
| | General Certificate | 2 | 0.22 |
| | Higher Certificate | 19 | 2.13 |
| | Honours / B Tech degree | 172 | 19.30 |
| | Intermediate Certificate | 5 | 0.56 |
| | Master's degree | 58 | 6.51 |
| | National Senior Certificate (Matric) | 20 | 2.24 |
| | Post-Doctoral Studies | 14 | 1.57 |
| *Level of Employment* | Entry level – new graduate | 55 | 6.17 |
| | Executive – expert/specialist/management. | 125 | 14.03 |
| | In-service | 22 | 2.47 |
| | Junior | 111 | 12.46 |

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| | | | |
|---|---|---|---|
| | Middle | 236 | 26.49 |
| | Senior – subject specialist | 284 | 31.87 |
| | Volunteer/Apprenticeship/Internship | 58 | 6.51 |
| *Trained in STEAM content* | No | 218 | 24.47 |
| | Yes | 673 | 75.53 |

### 3.2 Student enrollment trends in Science, Technology, Engineering, Arts and Mathematics subjects

Based on the findings, 63% of educators noted no decline in the number of learners enrolling for STEAM subject, and 37% reported a decrease. However, respondents pinpointed that there's been a significant decrease in learners enrolling for pure mathematics at a high school level (i.e., most student are opting to do maths literacy). These findings reveal a noteworthy contrast with previous research. Contrary to the participants' perceptions, [16] indicated that there is low student enrolment and high attrition rates in STEAM education enrolment. Participants pointed out that despite this, there are still several obstacles that prevent or discourage students from participating in STEAM course offerings. Approximately 210 respondents indicated that the decline in the enrolment in STEAM can be attributed to the perception of STEAM subjects as challenging, coupled with prevalent stereotypes. These stereotypes include misconceptions like the belief that computer science is only for men or that engineering is not suitable for women, fostering an environment of unwarranted fear and discouragement. Another prominent concern, raised by 137 participants, was the lack of teaching aids, resources, and infrastructure, highlighting potential deficiencies in the overall educational environment. Responses indicating poor academic performance and a high failure rate, totalling 51, suggest that academic challenges may deter students from STEAM subjects. Other factors contributing to the decline include inadequate foundation, insufficient interest, lack of information, and awareness (54 responses), as well as concerns about the quality of teaching and a shortage of competent educators (50 responses). Additionally, the complexity of the issue is further emphasized by factors such as lack of funds, lack of employment opportunities after completion, overcrowded classrooms, and socio-economic factors (Table 2).

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**Table 2: Reason for the decline of learners enrolling for STEAM subjects**

| | Reasons for decline | No of responses |
|---|---|---|
| **1** | No decline/Not applicable | 120 |
| **2** | Not meeting entrance requirements/Poor background/Poor foundation | 37 |
| **3** | Lack of employment after completion | 14 |
| **4** | Lack of funds/Budget constraints | 9 |
| **5** | General lack of interest in STEAM/Lack of information/Lack of awareness | 54 |
| **6** | STEAM Perceived as most difficult subjects to pass/Stereotypes/Fear of STEAM | 210 |
| **7** | Lack of teaching aids, resources, and infrastructure | 137 |
| **8** | Poor results/Poor performance in tests and exams/High failure rate | 51 |
| **9** | Lack of parental and/or role model support/Lack of confidence in learners | 40 |
| **10** | Poor teaching of the subjects/Shortage or lack of competent educators | 50 |
| **11** | Overcrowding | 18 |
| **12** | Alternative options (streams)/Drop out | 27 |
| **13** | Socio-economic factors | 11 |
| **14** | I don't know/I’m not sure | 19 |
| **TOTAL** | | **797** |

**3.3 Educators' self-assessment of content knowledge and pedagogy in STEAM disciplines**

The educators' self-assessment of content knowledge and pedagogy within the STEAM (Science, Technology, Engineering, Agriculture, and Mathematics) disciplines provides a comprehensive view of their perceived competencies and expertise in various domains as presented in Table 3. The findings show that 43% of respondents rated themselves as highly proficient in possessing content knowledge on STEAM. Demonstrating content knowledge on core STEAM courses is another area were educators’ express proficiency, with 41.64% considering themselves highly proficient. This suggests a solid understanding of the foundational courses and principles within the STEAM disciplines, reflecting a crucial aspect of effective pedagogy. The rest of the findings are depicted in the table below. Significant proportion of academics ratted themselves beginner and proficient. This represents a unique opportunity to upskill junior teachers to reach a highly proficient level in STEAM laboratory and clinical skills incorporation and use of technology in learning planning and delivery.

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**Table 3: Content Knowledge and Pedagogy**

| Content Knowledge and Pedagogy | Beginner | Proficient | Highly proficient | Distinguished |
|---|---|---|---|---|
| | % | | | |
| Possesses content knowledge on STEAM (Science, Technology, Engineering, Agriculture, and Mathematics). | 10.77 | 27.83 | 43.43 | 17.96 |
| Demonstrates content knowledge on core STEAM courses. | 11.45 | 28.62 | 41.64 | 18.29 |
| Demonstrates content knowledge on STEAM-related fields (i.e., research, language, and communication). | 10.66 | 30.53 | 40.97 | 17.85 |
| Demonstrates STEAM-related laboratory/clinical skills. | 21.10 | 31.87 | 32.55 | 14.48 |
| Exhibits knowledge on STEAM fields (content and skills) responsive to national goals and global concerns. | 13.92 | 31.43 | 37.26 | 17.40 |
| Plans, conducts, and disseminates STEAM-related research and activities. | 13.92 | 29.97 | 37.71 | 18.41 |
| Utilizes research outputs to enhance teaching and curriculum development. | 11.34 | 30.30 | 38.95 | 19.42 |
| Develops/Improvises new technology (software, laboratory equipment, and teaching materials) using locally available resources to advance the effective and efficient practice of the profession. | 18.97 | 31.20 | 32.55 | 17.28 |
| Uses advanced and research-based techniques and tools in teaching STEAM-related content. | 16.72 | 31.09 | 34.79 | 17.40 |
| Seeks out information on subject-related research, e.g., via journals or by attending conferences, trainings, and workshops | 10.66 | 26.82 | 41.08 | 21.44 |
| Act as a mentor in STEAM education activities | 14.03 | 29.07 | 36.03 | 20.88 |

### 3.5. Educators' self-assessment on course/curriculum/activity design

Table 4 presents educators' self-assessment on course/curriculum/activity design provides insights into their perceived proficiency levels in shaping and implementing STEAM education initiatives. Most educators demonstrate a high level of proficiency in understanding and developing STEAM education curriculum, with 38.50% rating and an additional 17.40% reaching the distinguished level. This suggests a collective commitment to grasping the intricacies of STEAM curriculum

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design, aligning with the contemporary emphasis on holistic and interdisciplinary approaches to education.

**Table 4: Course/curriculum/activity design**

| **Course/curriculum/activity design** | **Beginner** | **Proficient** | **Highly proficient** | **Distinguished** |
|---|---|---|---|---|
| | | **%** | | |
| Understand and develop STEAM education curriculum | 12.35 | 31.76 | 38.50 | 17.40 |
| Design STEAM education courses and activities | 15.94 | 32.88 | 36.03 | 15.15 |
| Create and modify appropriate content for STEAM education | 12.68 | 32.32 | 38.61 | 16.39 |
| Design and develop STEAM-related projects | 15.26 | 31.65 | 37.15 | 15.94 |

### 3.6 Transferrable and digital skills

Educators consider themselves proficient or highly proficient in key areas such as leadership development (40.29% highly proficient, 18.41% distinguished), presentation and communication skills (40.40% highly proficient, 20.65% distinguished), critical thinking, and problem-solving skills (41.53% highly proficient, 21.55% distinguished). Teamwork (42.54% highly proficient, 22.11% distinguished) and information management (40.18% highly proficient, 20.09% distinguished) also received commendable ratings. However, there is room for improvement in entrepreneurship skills (34.23% highly proficient, 17.73% distinguished) and the use of modern techniques for global competitiveness (38.50% highly proficient, 17.17% distinguished). Educators express a moderate level of engagement in seminars and conferences (36.92% highly proficient, 17.51% distinguished), while pursuing higher learning (36.03% highly proficient, 17.51% distinguished) and engaging in professional activities beyond teaching (36.25% highly proficient, 17.62% distinguished). These percentages offer a nuanced understanding of educators' strengths and areas for improvement, contributing to a holistic view of their capabilities in the diverse landscape of STEAM education. Figure 1 summarises these findings.

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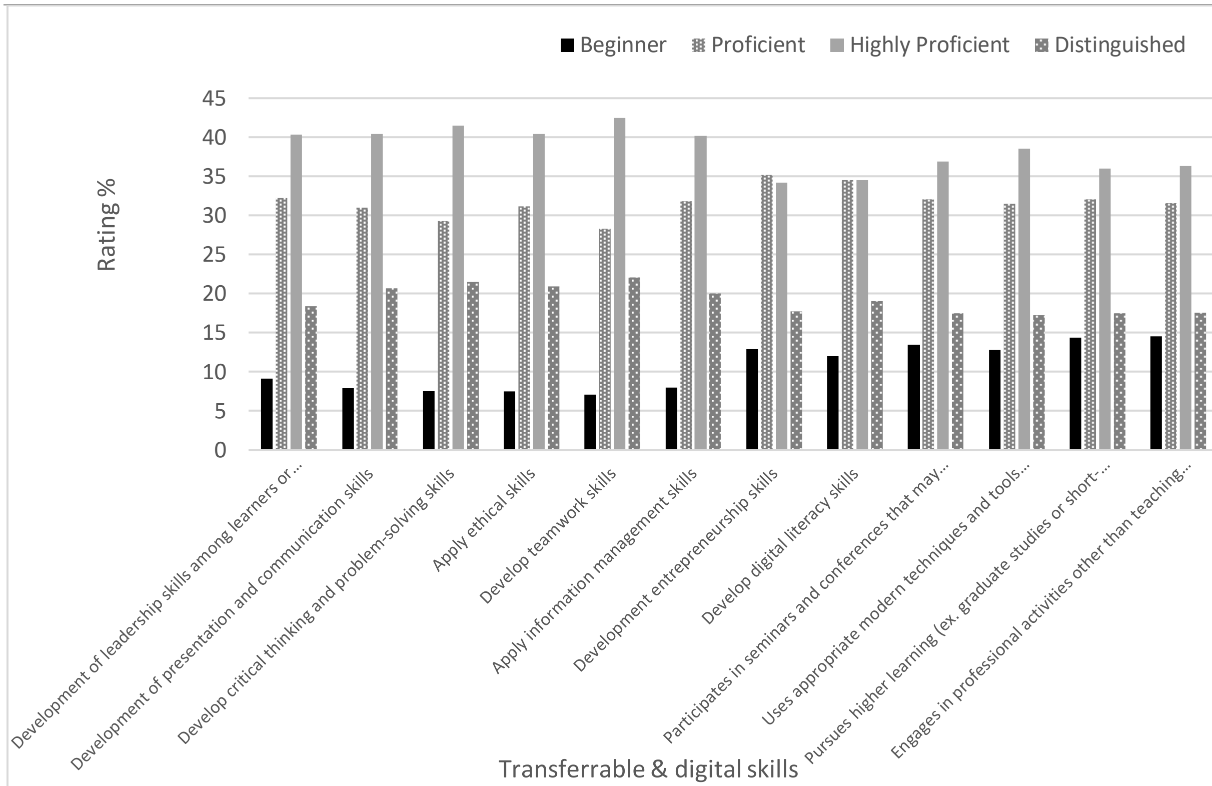


***Figure 1**: Transferable and digital skills*

### 3.7 Main challenges in the implementation of Science, Technology, Engineering, Arts and Mathematics in schools

There are numerous challenges that have been identified by the participants in the implementation of STEAM in schools. These are depicted in figure 2 below. They are summarized as follows:

- **Inadequate equipment and infrastructure.** Most of the participants reported inadequate equipment and infrastructure (491) as a major challenge in the implementation of STEAM in schools. This aligns with previous studies highlighting systemic challenges in the educational landscape. Studies by [28] emphasize the significance of sufficient resources, including equipment and infrastructure, for effective STEAM education. Additionally, [29] emphasises that having a robust infrastructure is crucial for facilitating effective learning and teaching. The availability of various tools, services, and resources that support educational goals is vital for both students and teachers. The concerns raised by participants as depicted in figure 2, echo the broader discourse on the need for improved educational material and lesson plans in STEAM subjects. The scarcity of suitable materials can hinder effective teaching and learning in these disciplines, emphasizing the importance of targeted interventions to address this issue.

- **Insufficiency of suitable educational material.** Other participants (333) cited Lack of suitable educational material and lesson plans as a hinderance in the implementation of STEAM in school. Congruent with these findings [30] indicated that the availability of learning resources in public schools across South Africa's provinces remains a critical subject. Unequal distribution and limited access to learning materials have posed significant challenges, particularly in historically disadvantaged areas. [9] stress the significance of curriculum resources in fostering meaningful STEAM learning experiences. Addressing this challenge involves a strategic emphasis on developing, curating, and disseminating contextually relevant educational materials. The literature underscores the pivotal role that quality educational content plays in creating engaging and effective teaching practices in STEAM subjects.

- **Language barriers.** Another challenge identified by the study pertains to a language barrier (284), affecting both educators and students. Literature, particularly the work of [31], emphasizes the importance of language-inclusive pedagogies in STEAM education. This highlights the need to recognize and address language diversity, ensuring that instructional strategies cater to varied linguistic backgrounds. A language-inclusive approach becomes paramount for fostering equitable access and comprehension across diverse student populations, promoting a more inclusive STEAM learning environment.

- **Lack of adequate training for educators.** The results confirmed that lack of adequate training for STEAM educators is also a major challenge (282). The reported lack of adequate training for educators aligns with the findings of [10]. Continuous professional development is emphasized as essential in the dynamic landscape of STEAM education. Ongoing training is crucial for educators to stay abreast of evolving pedagogical approaches, technological advancements, and interdisciplinary practices. The literature underscores the pivotal role of continuous learning for educators to effectively navigate the complexities of STEAM education and provide high-quality instruction. Additionally, the mention of large classes as a contributing factor to an unsuitable environment for teaching STEAM. Larger classes can strain resources, limit individualized attention, and potentially impede the hands-on, interactive nature of STEAM education.

- **Large classes**. Respondents also cited overcrowding as a challenge (257). Schools in rural areas suffer investment issues, and students are doubly disadvantaged because they come primarily from low-income families and attend underequipped schools. For example, 72% of rural secondary schools lack a science laboratory, and approximately 40% do not have indoor toilets. Even while urban schools are more prepared than rural ones, many are overcrowded. Overcrowded classrooms are unsuitable for teaching and learning which leads to higher grade repetition, age-grade distortion, and dropout rates, which ultimately hinders proper teaching and learning especially STEAM [32].

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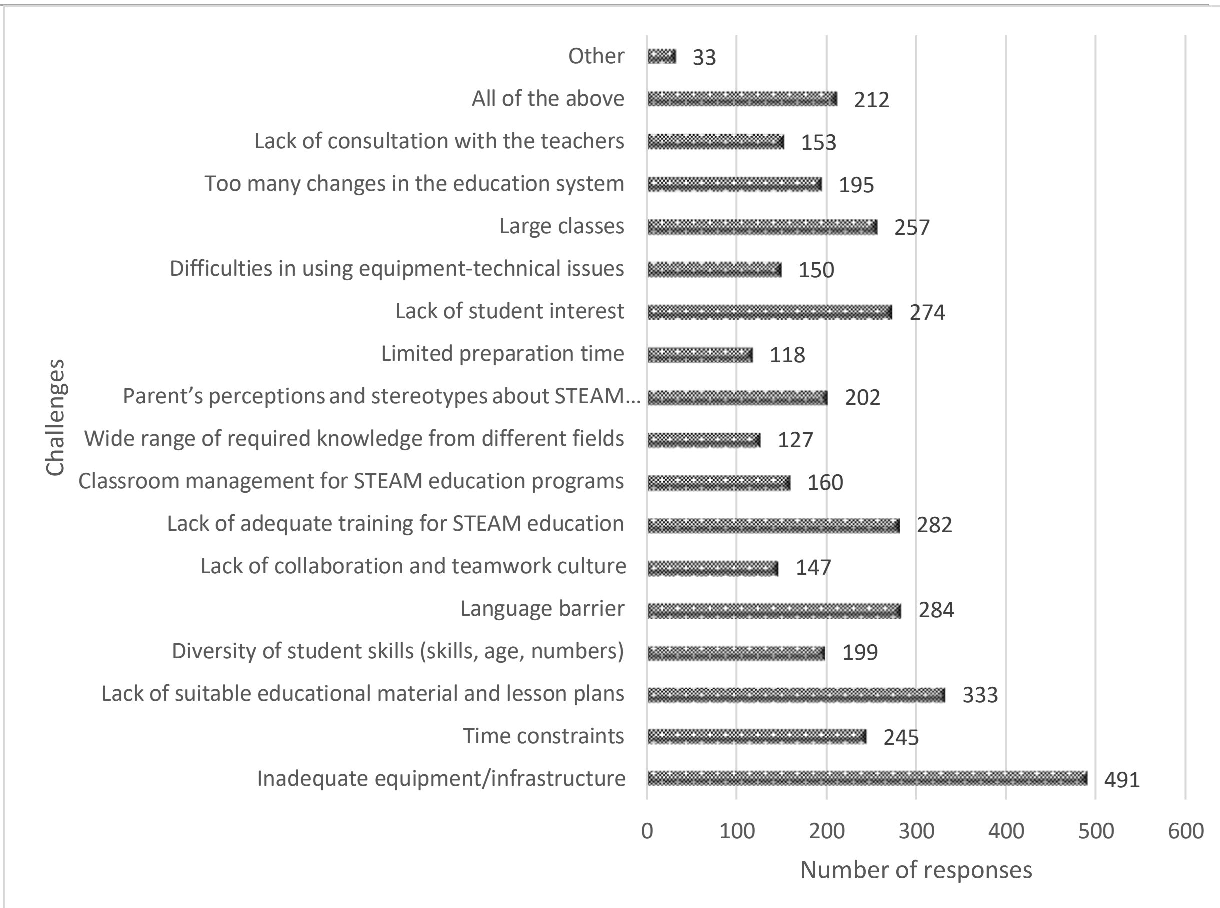


*Figure 2: Main challenges in the implementation of Science, Technology, Engineering, Arts and Mathematics in schools*

### 3.8 Benefit of the Development of Science, Technology, Engineering, Arts and Mathematics centres for teachers and students

Figure 3 presents an overwhelmingly positive response, with 87% expressing support for the development of Science, Technology, Engineering, Arts, and Mathematics (STEAM) centres for teachers and students, which reflects a strong consensus among the respondents. This high level of agreement suggests a widespread belief in the potential benefits that such centres can bring to both educators and learners. The 3% who expressed a negative viewpoint may have reservations or concerns about the effectiveness or necessity of STEAM centres. The 10% who responded with 'maybe' could indicate a level of uncertainty or a need for more information on the specifics of how these centres would operate and the potential outcomes.

Research by [33] underscores the positive impact of STEAM centres on students' learning outcomes. They found that these centres provide a conducive environment for hands-on, experiential learning, fostering a deeper understanding of complex concepts in science, technology, engineering, arts, and mathematics. The interactive nature of these centres promotes engagement and active participation, contributing to increased interest and enthusiasm among students.

Furthermore, studies by [34] emphasize the role of STEAM centres in professional development for educators. These centres serve as hubs for ongoing teacher training, equipping educators with

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innovative pedagogical approaches and the latest advancements in STEAM disciplines. The collaborative atmosphere within these centres encourages knowledge sharing among teachers, ultimately enhancing the quality of STEAM education in schools. Furthermore, [34] highlight the societal impact of STEAM centres. They argue that these centres serve as community hubs, facilitating outreach programs, and promoting public engagement with STEAM subjects. This broader impact contributes to building a STEM-literate society and cultivating interest in STEAM careers beyond the classroom.

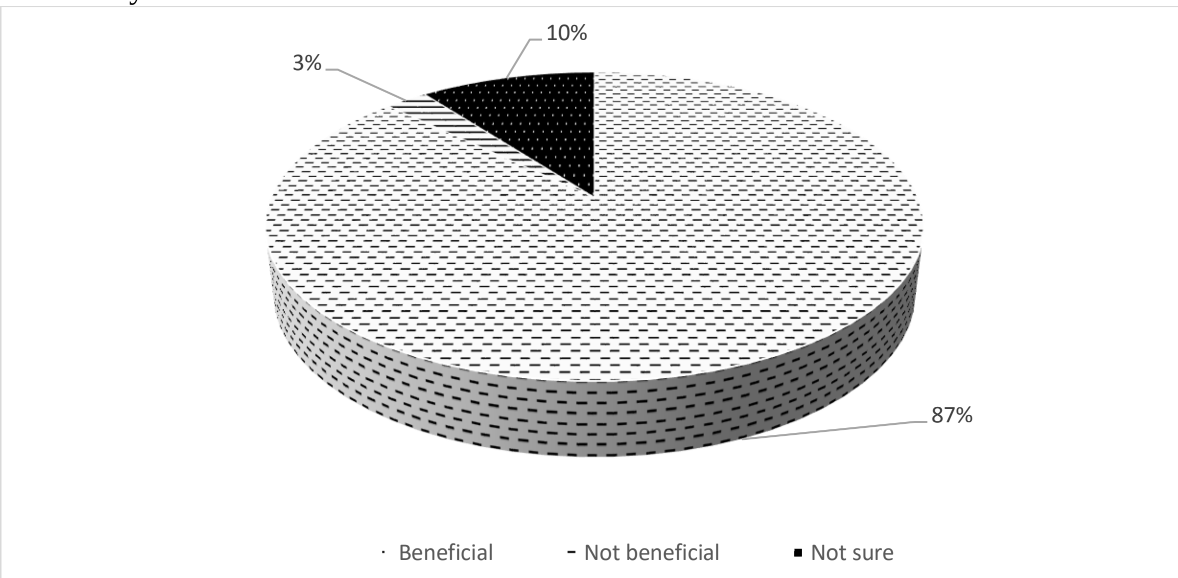


**Figure 3:** Benefit of the Development of Science, Technology, Engineering, Arts and Mathematics centres for teachers and students

## 4. CONCLUSION & RECOMMENDATIONS

STEAM education in the post-apartheid South Africa has emerged as a tool to equip students with the necessary skills and knowledge to thrive in a rapidly evolving world. It has emerged from this study that access to resources, infrastructure and teacher competency play a crucial role in influencing educational outcomes. The provision of adequate infrastructure such as libraries, laboratories, and technology-enabled classrooms will significantly improve learning environments. Additionally, investing professional development programs for teachers is essential in ensuring the successful implementation of STEAM education. While there are still challenges to be addressed in KwaZulu-Natal's educational landscape such as resource disparities between rural and urban areas or persistent inequalities stemming from historical legacies, it is evident that significant progress has been made towards creating an inclusive educational system that prioritizes equity and prepares learners for a rapidly changing world. By embracing STEAM education principles alongside ensuring access to resources and enhancing teacher competency levels, there is a great potential for a successful implementation of STEAM education and improved educational outcomes. Therefore, this study recommends the following:

- Implement targeted professional development programs (CPD) for educators at primary and secondary schools. These programs should focus on areas where educators have identified themselves as beginners or less proficient, offering hands-on training,

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workshops, and collaborative learning experiences to build expertise in STEAM-related laboratory/clinical skills, new technology development, and advanced teaching techniques.

- Encourage interdisciplinary collaboration among educators in primary and secondary schools. Establish collaborative teams that include individuals with complementary skills to enhance the overall STEAM education experience.
- Promote a culture of research and scholarly activities among educators in primary and secondary schools. Provide support for educators to plan, conduct, and disseminate STEAM-related research, encouraging the integration of research findings into teaching practices and curriculum development.
- Provide specialized training in the development and use of technology, software, and other teaching materials for educators in primary and secondary schools. Equip them with the skills to adapt and create innovative technological tools using locally available resources.
- Emphasize inclusive curriculum design in primary and secondary schools that considers diverse learner needs. Provide resources and training to help educators adapt their teaching strategies to accommodate students with varying abilities and comprehension skills, fostering a more inclusive STEAM education environment.
- Promote STEAM in Early Childhood Development centres (ECD's) by teaching STEAM through play and games.

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