Discover Education

Case Study

Pushing-in single-sex schools for enrichment of both enrolment and gender equity in STEM careers

Isack E. Kibona[1] · **Henry E. Nkya**[2]

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Abstract
Background Quality education has been emphasized by the world Sustainable Development Goal 4 (SDG4) of the 17 goals the world set to achieve by 2030. According to the twenty-first century skills, quality education obliges to equip learners to compete in the twenty-first century job market. In addition to enriching enrolment in science, technology, engineering and mathematics (STEM), leveraging of gender equity is indispensable.
Objectives This study revealed and processed data to guide education policy maker's decisions that could ensure quality education. Thus, the study shall lead to shape educational practices leading to achieve SDG4 timelines.
Methodology The authors studied results of the Certificate of Secondary Education Examination (CSEE) of 52 coeducations and six single-sex secondary schools in Mbeya city. Out of 52 co-education secondary schools, the researchers selected the best six secondary schools in performance and compared those to the six single-sex secondary schools.
Results The study revealed that, the six single-sex schools outperformed co-education schools. In addition, single-sex schools were richer of girls' enrolment than coeducation schools in STEM education. Although, coeducation schools leveraged gender equity in STEM performance, but there was an acute drop of number of number of girls in coeducation schools.
Conclusion This study calls for awareness and seek for more insights into the acute girl's school dropouts in best-performing coeducation schools, review of educational policies so that the world achieves SDG4 by 2030. Therefore, the study wide-opens that though challenged by many, single-sex schools are decent and remains an addition to achieve the SDG4.

Keywords Quality education · twenty-first century skills · STEM education · Mbeya city · SDG$

1 Introduction

Until 2015, many education worldwide challenges had been achieved including education for all and women participation in education [9, 57]. The question that clearly surfaced by then was the quality of education and for who [8, 58]? In order to answer the question, the United Nations established Sustainable Development Goal for Quality education (SDG4), a fourth out of the 17 Sustainable Development Goals (SDGs) in place [30]. SDGs was a global call into action to eliminate poverty, protect environment and guarantee freedom and harmony to all by 2030 [46]. Accordingly, by 2030 SDG4 has a role to guarantee inclusive, gender equity quality education and promote lifelong learning opportunities for all [60].

✉ Isack E. Kibona, iechibona@gmail.com; Henry E. Nkya, henryest600@gmail.com | [1]Department of Mathematics and Statistics, Mbeya University of Science and Technology, P. O. Box 131, Mbeya, Tanzania. [2]Tanzania Institute of Education, P. O. Box 35094, Dar Es Salaam, Tanzania.

Sub-Saharan and Southern Asia were among mentioned to intensify efforts to achieve SDG4, including vulnerable populations such as indigenous people, rural poor people, people with disability and refugees [17, 50]. Challenges sorted to achieve the SDG4 include lack of both trained teachers and adequate school facilities [19, 47]. Between 2005 and early 2020s researches conducted in the US revealed that STEM career jobs are increasing faster over non-STEM than ever [6, 42]. Concurrently, SDG4 is to enhance skills for youths and adults and links to the jobs in the twenty-first century [58], this marks a global shift in the orientation of quality education, thus promoting emphasize in STEM education as a back up to the twenty-first century skills in the job market [1, 12].

This study critically proposes a long time challenged alternative with evidence to operate single-sex schools [21] as decent for mitigation of not only poor enrolment in STEM education but also to leverage gender equity particularly between girls and boys in STEM education [23, 37]. Although Evans [18] argue that co-education empower girls in confidence and leadership compared to single-sex schools, however, it should be accommodated that sacrifice becomes necessary for some priorities. Thus, although teachers are trained and facilities are made available in co-education schools, it appears that teachers do inherently practice biased classroom interactions and pedagogy against girls ending up in favor of boys, not only that but Alneyadi and Wardat [2] argue that girls and boys learn differently [13, 20]. An introduction of artificial intelligence and machine learning such as chatGPT in teaching pedagogy has lessened challenges in a co-education class setting [24, 48]. However, in the grounds of research it is not deep-rooted [26] and teachers are not trained yet to carry the task because AI has just been introduced [3].

Interestingly, although Lee and Lockheed [32] asserted that single-sex schools offer more advantages to girls than boys, but in this study it appears that performance in single-sex schools of only boys exhibit better performance than co-education schools. That is an invisible line to note because in co-education boys appear favored in performance over girls. The situation is more serious in STEM subjects, co-education secondary schools are pointed to favor boys over girls in science, technology, engineering and mathematics (STEM) subjects [25]. Moreover, this study also revealed that in the final examinations of best co-education schools the number of girls is less than boys contradicting decent trends, suggesting that more girls drop out in the process of studies with time to final level, reasons may include poor performance [29].

2 Background and significance

2.1 Background of the study in Tanzania

Tanzania, like many other countries, faces significant gender disparities in STEM education and careers. Historically, there has been an underrepresentation of women in STEM fields, limiting their access to lucrative and high-demand career opportunities [39]. This gender gap in STEM is influenced by various factors, including societal stereotypes, limited access to quality education, and a lack of role models [51]. Addressing these disparities is crucial for promoting inclusivity, equal opportunities, and socioeconomic development in Tanzania [45].

2.2 Significance of the study

Understanding the potential benefits and challenges associated with single-sex schools in promoting enrollment and gender equity in STEM careers can provide valuable insights for policymakers, educators, and stakeholders [52]. Particularly, examining the situation in Mbeya City of Tanzania, this research can contribute to the existing body of knowledge on strategies to bridge the gender gap in STEM. It can shed light on the effectiveness of single-sex schools as a means of empowering girls and enhancing their participation in STEM careers. The findings inform evidence-based policy decisions, educational reforms, and interventions aimed at promoting gender equity and more enrolment in STEM education. Moreover, the study's significance extends beyond the local context, as it adds to the global discourse on strategies to address gender disparities and enrolment in STEM. By presenting a case study from Tanzania, it can offer comparative insights and contribute to the broader understanding of the potential impact of single-sex schools on enrolment and gender equity in STEM careers worldwide.

3 Literature review

Single-sex schools have a longest history and involved men-only schools, for instance, early civilization schools were all men schools [40, 53]. This is considered one of the very reasons teaching pedagogy particularly in co-education are inherently in favor of males [22]. Coeducation schools had a significant evolution since 1880s as a struggle to address gender equality and more surfaced during World War I [7]. By then, in colleges women had not only separate colleges but also separate program against men [22]. In the 1970s, very few women-college remained, pertaining to some conservatisms who believed that Women-College had better results of women graduates over women graduates from coeducation [22].

For the same reason (gender equity), educational policy makers introduced single-sex schools (girls-only schools) later in the 1960s and 1970s [28]. Research of more insights about single-sex schools dates back to the 1960s and 1980s especially in North America as an effort to understand girls and women performance in single-sex schools [31]. In this regard, most of the authors have stressed specific advantage of single-sex schools to female in the world of academics [33]. In the late of the twentieth century, some researches learned that there is gender disparity in science and mathematics [34]. Disparities were associated to masculinity, culture and overall stereotype about science and mathematics toward girls [43, 54]. In 2000s, a term STEM education introduced by the USA National Science Foundation (NSF) following decrease in man power in the US technology and economic-socio development, recognizing that STEM career could fit to increase manpower in twenty-first century [5, 16, 35, 38]. Clark Blickenstaff* [13] insisted under-representation of women in STEM careers in the last 30 years by then. Thus, most of the writers were about enrichment of girls in STEM [59]. O'Connell and McKinnon [44] proposed reshaping the gender norms, these considered as serious barriers against gender equity and inclusion, and supported by other researchers [4, 11]

Following the challenges observed in the course of evolution of education systems [56], this study is an add-on to address challenges to achieve quality education according to UN. In 2015, the UN establishment 17 SDGs, including SDG4 [41]. SDG4 has defined quality education and the timelines of achievements [49]. Despite setback of single-sex schools according to the literature, this study demonstrates more benefits in the manner that outweighs the setbacks. Moreover, the researchers extend the significance of boys-only schools over co-education and the role of physics and mathematics for sustainability of STEM careers.

4 Research objectives

This study serves to emphasize single-sex schools as one of the solutions to enhance success of the SDG4 in Tanzania and way up to all sub-Saharan Africa, developing countries and vulnerable groups.

4.1 Specific objectives

- Increase student enrolment in STEM education as a foundation for future STEM careers
- Guarantee leveraged gender equity in quality education.
- Raise awareness to education policy makers and other stakeholders to make informed decisions in education investment.

5 Data and methods

5.1 Study design

The Authors designed the study for all 58 secondary schools in Mbeya city with 7959 form four secondary school graduates by then candidates sat for Certificate of Secondary Education Examinations (CSEE) in the year 2022. Mbeya city secondary school girls enrollment exceeds number of boys [27] There were only six single-sex schools in the city (three girls-only and three boys-only) with 677 candidates of which more than half were girls.

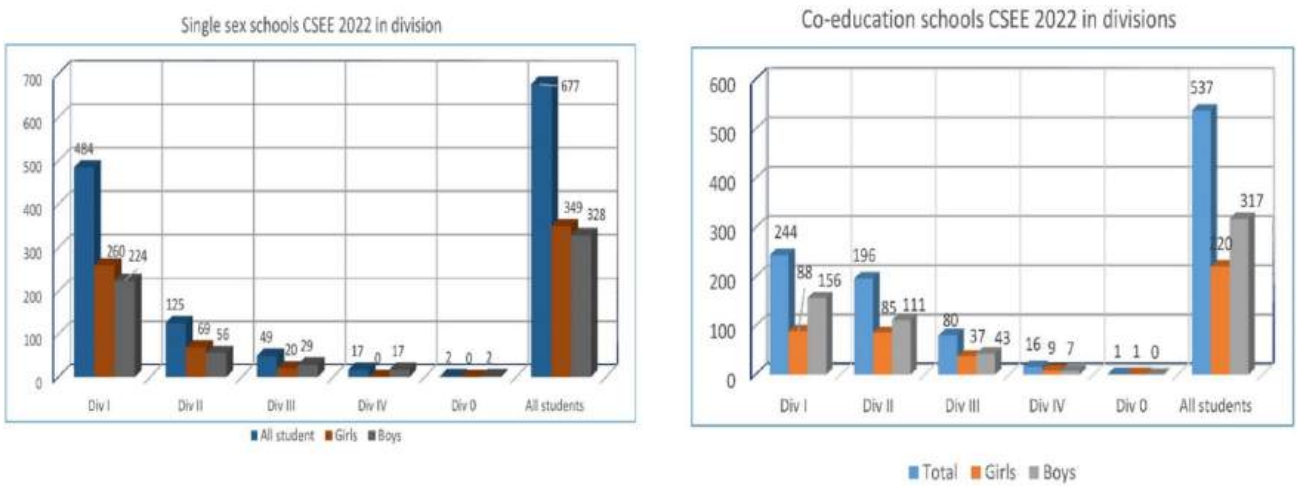

Fig. 1 Schools CSEE 2022 results in divisions

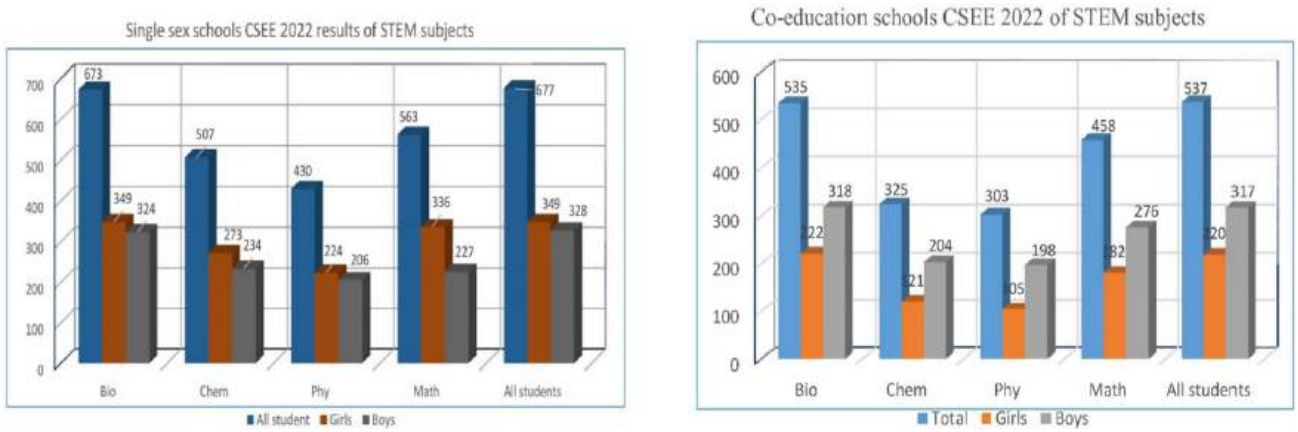

Fig. 2 Schools CSEE 2022 performance in STEM subjects

5.2 Sample selection

The study involved purposeful sampling by selecting the best top in performance of six co-education schools out of 52 secondary schools and compare performance to the only six single-sex schools in the city.

5.3 Data collection methods

The authors recorded CSEE 2022 results in divisions according to publication by the National Examination Council of Tanzania (NECTA), and extended the records to observe performance in STEM subjects [27]. While recent girls' enrolment in secondary schools is higher than boys in Tanzania [36], overall number of girls in the best performed coeducation schools is lower than boys. In this regard, student dropouts in the CSEE estimated following the fact that at least in the earlier classes' girls' enrolment was greater than boys.

Accordingly, results conveniently presented in bar charts by separating performance in divisions and in STEM subjects for both singles-sex and co-education schools as in Figs. 1 and 2. A minimum pass (D grade) in STEM subjects considered pass in this context.

5.4 Data analysis

The study analysis categorized into three, compare performance between single-sex schools and co-education schools both overall and in STEM subjects, chi-square test of gender equity in the best six CSEE performed co-education schools and finally, compare number of girls between single-sex-schools and co-education schools in the final year of completing CSEE.

5.4.1 Performance

Refer Fig. 1, despite co-education secondary schools being the best among 52 co-education schools in the region, less than 50% of students overall performance fall in division one with less girls in this division. On the other hand, more than 71% of students in single-sex schools falls in division one, with more girls in this division. For the case of STEM subjects, number of physics passes in girls is approximately half the number of passes in boys, unproportioned to the ratio of girls to boys, Fig. 2.

5.4.2 Gender equity Chi-square test

Performance of students in biology, chemistry, physics and mathematics tabled along with gender as girls and boys as depicted in Table 1. Null and alternative hypothesis testing involved by Chi-square (χ^2) test to obtain a statistical decision.

Numbers in parentheses of Table 1 are theoretical expectations of gender equity. Evaluation of chi-square took five steps to justify whether gender had an influence in the performance of STEM subjects for selected co-education schools

Step 1: Null (H_0) and Alternative Hypotheses (H_1):

H_0: For the students in Mbeya city from the best performed six top co-education schools, gender had nothing to do with performance in STEM subjects of the CSEE in 2022.

H_1: For the students in Mbeya city from the best performed six top co-education schools, gender had an influence in performance of STEM subjects of the CSEE in 2022.

Step 2: Stated confidence interval: $\alpha = 0.05$

Step 3: Degree of freedom (df) and the critical value (p - value):

$df = (rows - 1)(columns - 1) = (2 - 1)(4 - 1) = 3$, so critical value, p = 7.81.

That is if χ^2 is greater than 7.81, we reject H_0 otherwise it is accepted.

Step 4: Test statistic $\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$, where $f_e = \frac{f_c f_r}{n}$ and $f_0 = observedfrequence, f_e = expectedfrequence, f_c = frequenceofthecolumn, f_r = frequenceoftherow, n = totalnumberofsubjects$.

Step 5: Theoretical pass expectations: Girls expected to pass biology in first cell of Table 1,

$$(Girls, biology)_{11} = (535 * 220)/537 = 219$$

$$\chi_s^2 = \sum \frac{(f_o - f_e)^2}{f_e} = 7.09 < 7.81 = p.$$

Table 1 Passes in STEM subjects

Gender	Biology	Chemistry	Physics	Mathematics	Total
Girls	219 (219)	121 (133)	105 (124)	182 (188)	220
Boys	316 (316)	204 (192)	198 (179)	276 (270)	317
Total	535	325	303	458	537

Therefore, we accept the null hypothesis.

5.4.3 Girls enrollment in the CSEE

Overall enrolment of girls in Mbeya city secondary schools is greater than boys, in brief even individual schools many reflect the same. However, it is so vivid that in the six co-education schools selected number of girls are other way around. There is a significant gap that we have fewer girls overall, and more stunning that this trend persists even in the performance of students. Particularly in physics, performance of girls have dropped to almost half of the boys. On the other hand, we have more girls overall in single-sex schools, interestingly, this number is maintained in the performance of STEM subjects. As for physics, number of girls have maintained the position of being more than boys are. Other STEM subjects are evident maintaining number of girls, Fig. 2.

5.4.4 Role of physics and mathematics in STEM subjects

Note the plots in Figs. 3 and 4, plots represent number of students who took and pass a given STEM subject. In this regard, a least number of students took and passed physics. On the other hand, almost all students took and passed biology in all schools. Note the plots in Fig. 4. Why a mathematics plot overlaps other plots as seen in physics, biology, or chemistry? The reason is that mathematics is independent, thus has its own way. Plots in physics, chemistry, and biology were in clear separated patterns, a physics plot took the bottom of all and biology at the top of all, chemistry took the way in the

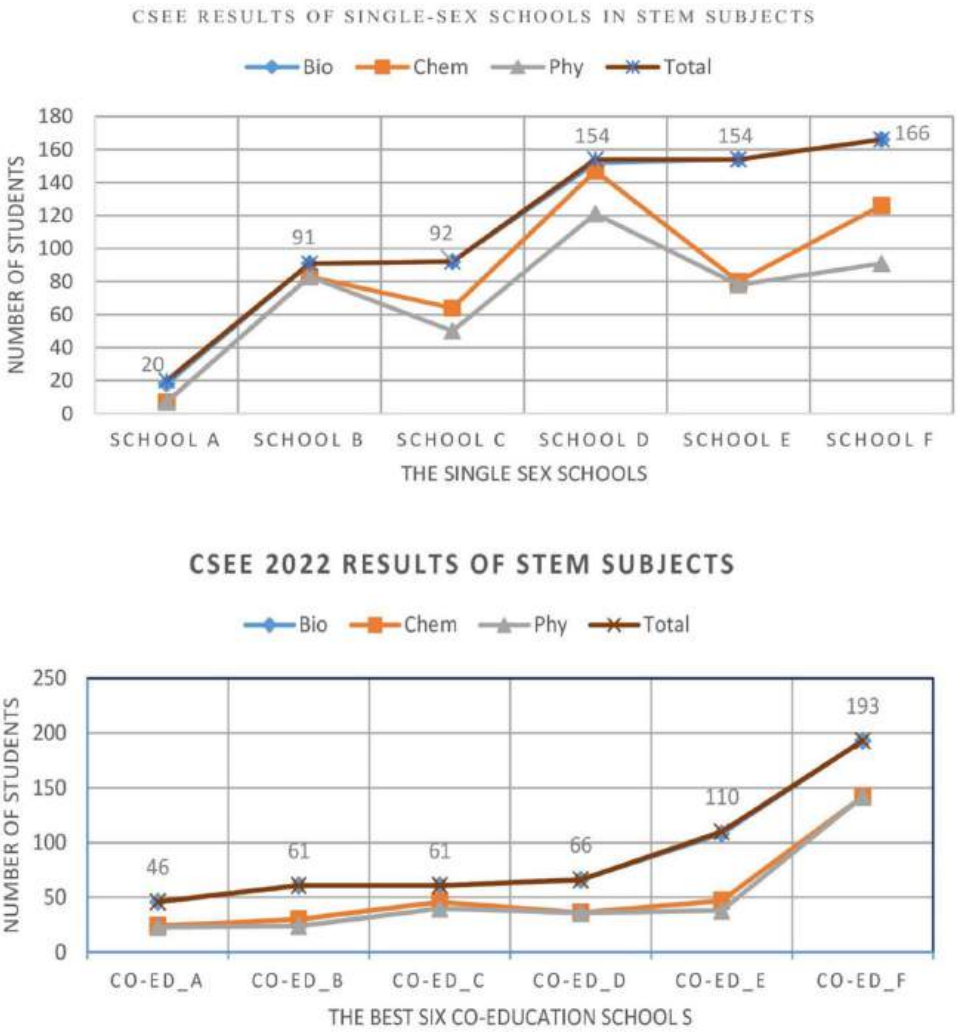

Fig. 3 Patterns of performance plots in biology, chemistry and physics

Fig. 4 Patterns of performance plots in biology, chemistry, physics and mathematics

middle. When mathematics plot included, it crossed other STEM subjects' plots, Fig. 4. On the other hand, physics plays a central key in STEM subjects [10], particularly in biology and chemistry.

Some researchers regards ability in mathematics could lead to student better performance in STEM subjects [14, 15]. Plots of performance in physics, chemistry and biology pattern with non-overlapping graphs are not a coincidence, the three are interdependent, that physics spans into chemistry and biology, and the vice versa is not true. Thus, a student to sustain in STEM education physics is indispensable. However, physics do not stand-alone, needs mathematics as its language. Therefore, separating a physics student from mathematics do compromise not only in physics but also in STEM education. This is how mathematics comes into STEM education. Therefore, to boost performance in STEM education,all STEM careers prospects intending to sit for CSEE are recommended to compulsory take both physics and mathematics. One of the reason is that most of the physics concepts are foundations in other STEM subjects [55].

The best six co-education schools finalized students in CSEE with less number of girls than boys but also it appears that for possible good performance a size of class in co-education need smaller number of students to comparable single-sex class for management reasons.

6 Results and discussion

The only single-sex schools studied in the city have demonstrated stunning results against six top best co-education schools out of 52 schools. In addition, single-sex schools have maintained the number of CSEE graduating students evidenced in girls' performance over boys. On the other hand, it was estimated that more than 31% dropouts against CSEE for girls had occurred in co-education schools. This suggests that in the struggle for education female students are safer academically when studying as single-sex students. It is important to note that single-sex schools in this study includes

boys-only schools. In the literature boys perform better than girls in co-education schools do, interestingly also boys perform better in only-boy's schools than in their comparable co-education schools. Thus at some point, neither girls nor boys are safer academically in co-education schools.

Gender equity appears great in the analysis of co-education schools, however, this is misleading because if we could account for the number of dropouts for boys and girls as failures before enrollment into CSEE the analysis would go otherwise. So gender equity is in the survivors of CSEE of which fewer girls over boys survive in the way of co-education. Nevertheless, gender equity analysis suggest student enrolled in the CSEE experienced no gender disparities in the co-education schools, and practically there is no dropouts toward CSEE. More than 31% dropouts for girls in co-education schools reminds us that while we have female students who surpass challenges that results in streaming same class with boys, we also have girls who best suit in single-sex schools. Therefore, parents and guardians should make educated choices whether to place their children in single-sex schools or co-education schools.

Number of girls enrolled in the CSEE lowered in co-education school in the end, this is a strong point to establish single-sex schools so to boost STEM education enrollment of girls and advantage in gender equity. Mbeya city like other cities in Tanzania is not an exception in struggling to address enrollment and gender equity gap in STEM subjects. Based on the analysis of this study it is an appreciation that single-sex schools saved the life in education of graduating secondary school girls. This study does not suggest transformation of all schools into single-sex schools, refer to the setbacks [18], however, the study proposes recognition, adjustments and permission of single-sex schools to collaborate and harmonize a united effort for quality education according to SDG4.

7 Conclusion

It has been pointed a lot of disadvantages in single-sex schools including lack of experiencing cross-gender leadership, cross-gender socialization, social-emotional accomplishments and so on. However, this study sums that regardless of all that, educational stakeholders need to recognize the payoffs in single-sex schools. Single-sex education is conducted at some points in lifetime and not always, in addition students can take some levels of education in single-sex schools and others in co-education basing on their maturity. Incidentally, what students miss in single-sex schools are not only available in co-educations, partly are available in other social interactions like vacation, other educational levels, holidays, internship and the likes.

More than 31% dropouts for girls on the way to final examination is a threat to gender equity in the future careers particularly in STEM. This directly compromise SDG4. Education policy makers beyond parents and guardians need to provide favorable grounds for parents and guardians to shape them proper choice makings as where to place their children quality education achievement according to SDG4.

Moreover, the Authors are recommending to all STEM career prospect students, preparing for CSEE must consider taking physics and mathematics to enhance sustainable future in STEM careers. Thus, single-sex schools are decent as evidenced in this context for special achievements, to increase enrolment in STEM education, backup of STEM careers, and leverage gender equity for enhancement of SDG4.

Thus, this is an advice to education stakeholders to review education policies and consider single-sex schools to take a role of add-on in education and not as spearhead or pioneer of SDG4.

8 Recommendations future work

Research is required to seek for insights as to why best-performed coeducation schools have more than 31% dropouts of girls before attempting CSEE, not only that but also overall number of students in coeducation schools is lower than number of students in single-sex schools suggesting serious dropouts for boys as well.

8.1 Limitations and strength of the study

The study dealt with final examination results (CSEE) of students in single-sex and co-education schools to portray a prevailing situation in the performance of the schools. In this regard, authors challenged to detail information to all WHY questions. The strength of the study was to raise awareness for taking action to address challenges and provoke other researcher for further insights to the WHY questions.

Author contributions Isack Ephraim Kibona designed the study, collected data, did the methodology, data analysis and discussion and shared to conclude with Henry Estomihi Nkya.Henry Estomihi Nkya wrote the introduction, literature review and participated in setting objective of the study.

Data availability The full dataset is available: Mendeleev repository (https://doi.org/10.17632/k7jjrs4wnk.1).

Code availability School names coded used in analysis of the data.

Declarations

Competing interests The author declares there is no conflict of interest to publish the manuscript.

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