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Mathematics Algorithms Gaps from Students Perspectives: A Case of Selected Community Secondary Schools

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ABSTRACT
The mixed case study research involved 120 students from community secondary schools located at Chanika Ward in Dar es Salaam were selected using non-probability approach deployed purposively technique. Objectively the study intended to determine and examine the school based contextual practices leading gaps in attainability of mathematics algorithms from students' perspectives. Data were collected using four ranked Likert scale questionnaire and FGD thereafter analysed using Ms Excel and thematic content. The findings showed that students were experiencing mathematics algorithms gaps in 22 concepts supposed to be covered in the syllabus from form one to four; the identified classroom contextual gaps were categorized into ICT resources, pedagogical and students aspects. Recommendations were made for stakeholders to support schools, teachers and students with the digital and technological tools, creating supportive learning environments fostering creativity, collaboration, critical thinking and problem-solving skills built within Mathematics concepts algorithms fore-fronting the 4IR practices.
Keywords: *mathematics; algorithms; pedagogies; fourth industrial revolution (4IR)*

1. INTRODUCTION

The Fourth Industrial Revolution (4IR) as the current in truck era brought the new ways of performing multi-sectoral activities driven by changes replicated into what Liu et al. (2023) stimulated as the advancement of Smart Technology, Artificial Intelligence, Robotics and Algorithms (STARA). Globally, the deployment of interlinked and integrated human and robotic-technologies are throughout observable in utilization of Artificial Intelligence (AI), Internet of Things (IoT), robotics, Machine Learning (ML) and big data analytics tools instigated the enthusiastic paradigm shift in sorting various social-economic activities (Keleko, 2022; Chhillar & Aguilera, 2022; Rejeb et al., 2022; Singh et al., 2023; Chalmers, MacKenzie & Carter, 2021; Oosthuizen, 2021). Apparently, mathematics algorithms are considerable components for development and deployment of STARA innovations, as are providing systematic and logical methods for problems solving and performing computations (Pereira et al., 2023; Liu et al., 2023).

Afterwards, the development of 4IR technologies are depicted into various mathematics concepts providing the grounds for manipulation and performing analytics in big data, creation of algorithms, determining variables, design models, frameworks and systems for processes optimization hence shaping practices (Serey et al., 2023; Tao, 2021). According to Oladele et al. (2022), mathematics concepts play the vital roles in digitalization and technologies deployments borne to the 4IR. Apparently, within mathematics there are well-defined algorithms comprised of the language with finite sequence of rigorous instructions for Mathematical problems solving (Dutta & Patel, 2022). Moreover, algorithms are built in the philosophy of mathematics languages empowering problems solving with set of instructions

for computer sciences and programming (Sapaty, 2022*;* Luger, 2023). Subsequently, the captivity and understanding of the mathematical algorithms became potential for realization and integration of advanced technologies experienced in the 4IR practices (Rejeb et al., 2022; Singh et al., 2023).

Superficially, in order to meet with the requirements of digital era, today's students are apprehended to be conversant to multiple mathematical algorithms that are categorized into arithmetic algorithms (Abualigah et al., 2021; Hu et al., 2022), algebraic algorithms (Bråting & Kilhamn, 2021), and geometric algorithms (Meza, 2021). Nevertheless, the uptakes of 4IR depend on mathematical variables that possessed step-by-step algorithms procedures being deployed in problems-solving or tasks performance (Pereira et al., 2023). For example, the statistics concepts such as regression analysis, data mining, deployed during the designing of mathematical tools and optimization models within the machine learning for improving efficiency and performance (Abideen et al., 2023). Likewise, utilization of algorithms found within the graph theory in developing the networks (Singh, Kataria & Singhal, 2019). Furthermore, solving complex mathematical problems supplemented with big data in efficient manner is grounded on numeral analysis approaches found in built-in algorithms of numerical integration, differential equations, and finite element analysis fore fronted within the 4IR tools and digital instruments possessed procedures to sort complex and challenging mathematical aspects in analysing the data analysis that are beyond normal human capabilities (Zhang et al., 2021; Dobbe, 2021).

Zhang et al. (2020) insisted on algorithmic contents found within mathematics concepts pertained into linear algebra, calculus, and probability theory in equipping learners with logics, critical thinking, problem solving and analytics competences. Similarly, Buntak et al. (2021) cemented on the benefits brought by robotics and AI in enabling students to capture different mathematics concepts and optimization of digital operationalization in handling manufacturing complex systems processes, predictive maintenance, industrial productivity optimization and supply chain management to mention few. Apparently, Górriz et al. (2020) pointed that, digital technologies are abundantly useful in developing the unstructured and complex volume of data generated every day that need Data Science (DS) algorithms. Besides, the frequency of volumes of big data generated raised senses for developing and creation of advanced sophisticated mathematical algorithmic tools, theories and models (Pramod et al., 2021).

Yet, mathematics concepts such as statistics, calculus, linear algebra, probability and graphical theories are appropriate on enhancement of deep learning and artificial intelligent (Ghosh & Math, 2022; Li & Liu, 2022). Certainly, the extraction of complex insights found within datasets, identification of reflective patterns, trends and automation decisions are useful in developing predictive social economic models so as to design the proactive solutions (Jiang et al., 2023; Shu & Ye, 2023). Subsequently, the algorithms obtained in mathematical are pre-requisite in unique professional trainings for highly payable professional such aerospace, engineering, computer science, and information technology (Meyer & Norman, 2020; Curiel-Ramirez et al., 2022). Based on that stance, new digital era requirements enforced education systems and its components to change practices; integrating automation for future works competences (Howcroft & Taylor, 2022). Moreover, mathematics resources investment in the classroom context is essential particularly the deployment of analytical and algorithmic focused on digital related simulations apprehended to sort the real life problems (Tao et al., 2021; Howard, 2019).

Furthermore, Hariri (2019) and Chalmers et al., (2021) disclosed on the power brought by the 4IR in information and analytics for improvement in forecasting performance. Likewise, the deployment of advanced 4IR technologies for sorting and handling information and data are victimized through cyberattacks (Zwilling et al., 2019). Subsequently, Khan et al. (2020) insisted on the cryptocurrencies and decentralized applications such as dApps being attributed to the blockchain technologies innovation and

development. Certainly, Prasad et al. (2022) proclaimed on the mathematical algorithms built on concepts of numbers, group theories and elliptic curves that are supportive to the cryptography topologies useful in blockchain. Also, the mathematics algorithms concepts are fore fronted in the development of secured communications through cryptography and data encryption to enforce cyber security and data privacy protection (Rawat et al., 2019; Xu et al., 2022).

Tremendously changes brought by technologies in 4IR raised questions on readiness of Tanzanian secondary schools students to become digital invaders. Despite many areas that need intervention, still the contribution of technologies deployment in education is questionable. Apparently, orientation, sensitization, motivation and training to mathematics teachers for deployment of constructivism and multiple intelligence approaches in changing classroom practice are the experiential gaps; stagnant approaches in engaging students in reaching the mathematical algorithms in acquisition of cognitive, psychomotor and affective competences to became active practitioners in the digital era. However, todays' mathematics students' performance as indicative component for technology aggression is doubtable in developing and utilization of supportive digital tools, apps and devices for automations henceforth curbing todays' and future social-economic challenges (Kyaruzi, 2023; Howcroft & Taylor 2022). Moreover, is revealed that in Tanzania students are holding individual subjectivism, anxiety and phobia leading difficulties in capturing, designing, developing and deploying mathematics algorithms and concepts in different social-technology related solutions (Kyaruzi, 2023). Deceptively, students are experiencing multiple psycho-cognitive that are contextually leading to dislikes and poorly mathematics subject performance countrywide (Stephen, 2023; Kihwele & Mkomwa, 2022).

Today's students are agents for deployment of digital resources and technological tools for future works (Howcroft & Taylor, 2022; Howard, 2019). Although mathematics plays the crucial role in driving innovations and technologies found in 4IR; in Tanzania students' mathematics practices and results are unconvincing as are tremendously diminishing alarming the digital era takeoff. Evidently, in five years mathematics performance for Certificate of Secondary Education Examination (CSEE) showed the pass rate being 20.02% (2018), 20.03% (2019), 20.12% (2020), 19.54% (2021), and 18.12% (2022) (https://necta.go.tz/csee_results). Mathematics subject being compulsory for every student in basic education encompassed pre-primary, primary and ordinary secondary showed the need to identify, the nature of topics, contextual practices and set mechanisms and address the replicated gaps to build future developers, designers and deposition of 4IR simulations (ETP, 2014; Kihwele & Mkomwa, 2022; Stephen, 2023; Tao et al., 2021). Based on that stance the study was significantly investigated Mathematics algorithms gaps found among selected secondary school students alarming on realization of the 4IR practices.

In order to align with those justifications, the study based on the specific objectives of:-

i. Determine the Mathematics algorithmic contents gaps among secondary school students for algorithm realism.
ii. Examine the classroom contextual gaps hindering students to attain the mathematics algorithms realism

2. METHODS

The mixed case study design was conducted at Ilala Municipality, Chanika Ward, Dar es Salaam, Tanzania. Certainly, cross sectional approach was employed for collection of the qualitative and quantitative data through administering four ranked Likert scale questionnaire and Group Discussion (FGD). However, non-probability approach deployed purposive technique was utilized in selection of 6 community secondary schools with high failure rate in Mathematics; whereas in each 20 school

respondents were selected to make the total of 120 respondents. Further, 32 itemed Likert questionnaire categorized into 22 on mathematics concepts gaps and 10 for classroom practices were administered to 120 students. Afterwards, 30 respondents distributed into 6 groups each comprised of 5 respondents were administered the FGD to get insight on experienced and classroom contextual gaps hindered acquisition of the mathematics algorithms realism. The collected quantitative data were analyzed using Ms Excel the thematic content was deployed in qualitative data nature. The findings were triangulated in presentation through narrative summary Tables and Cumulative Figures.

3. RESULTS AND DISCUSSION

Mathematics Contents Gaps Among Students

Apparently, the findings showed that there were 22 mathematics concepts found in the ordinary secondary school syllabus form one to four students were marginally possessed different algorithmic gaps as summarized in Figure 1 (a) and (b). Subsequently, the findings disclosed that students' levels of understanding and highly understanding were significantly below 20% in the concepts of Probability, three dimensional figures, circles and spheres, vectors and geometric transformation.

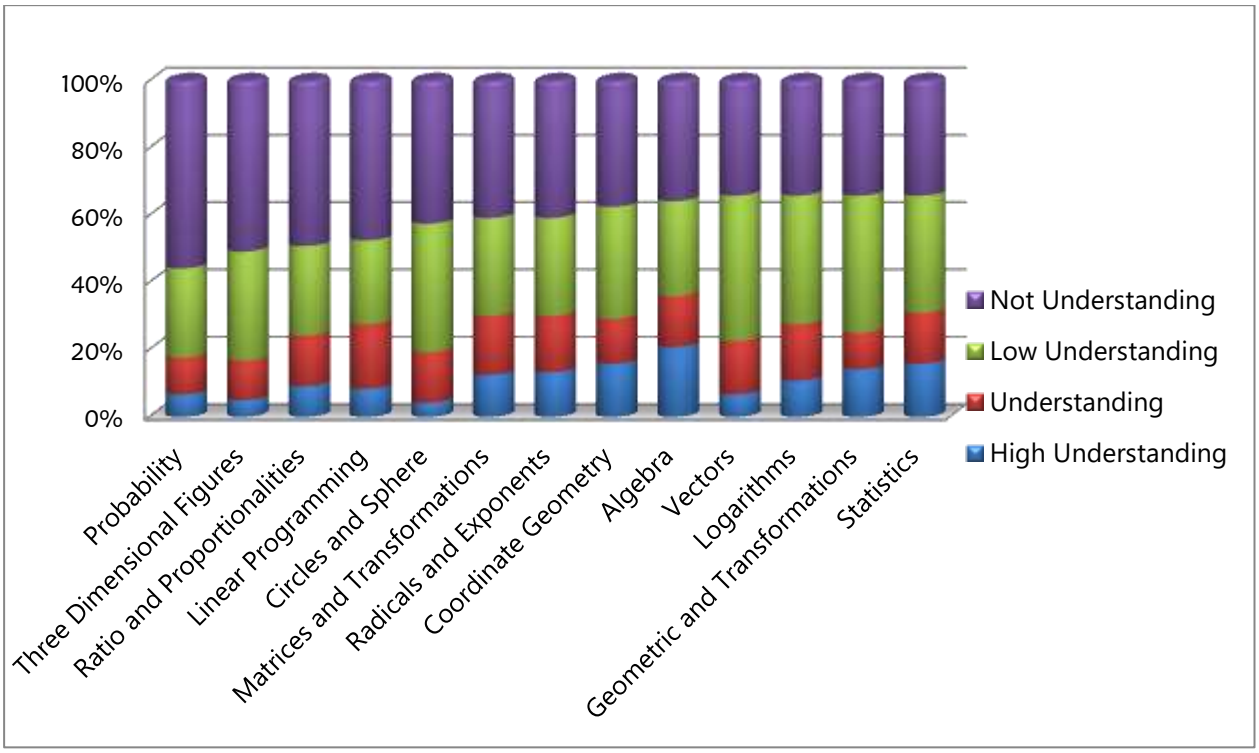

Figure 1(a). Identifies mathematics algorithms concepts gaps among Students

Besides, the level of captivity and understanding of the linear programming, matrices and transformation, radicals and exponents, coordinate geometry, statistics, algebra, logarithms, geometric transformation, sets, Pythagoras theorem, trigonometry, congruence and similarities, sequence and series algorithms were relatively between 20% - 40%. Also, was found that the algorithms on the concepts of functions and relations, areas and perimeters and numbers were understood by students in the levels of 40%-60%. Subsequently, students were significantly performed well in capturing accounting algorithmic concepts as the level of understanding was 60%.

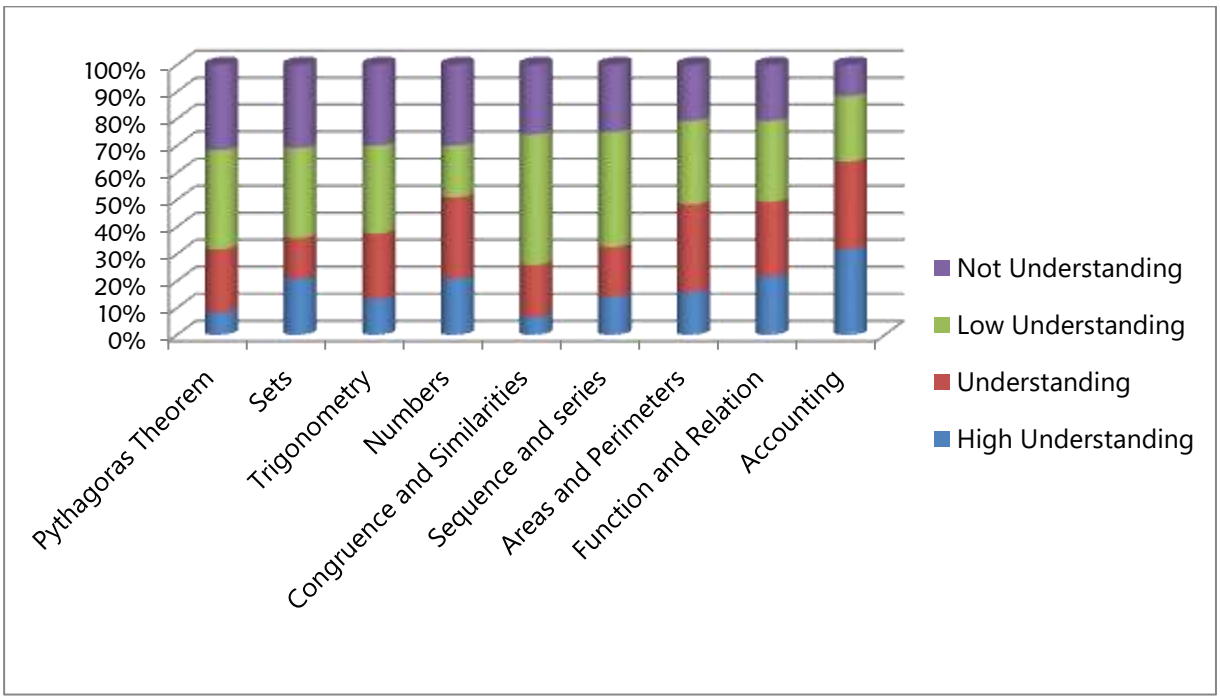

Figure 2(b). Identifies mathematics algorithms concepts gaps among Students

Classroom Contextual Gaps in Mathematics Algorithms Realism

Students in mathematics classrooms were affected by the contextual realities as was presented on the emerged themes obtained from the FGD. The emerged themes and subthemes virtually into ICT resources, pedagogical and students' aspects are summarized in Table 1.

Table 1. Identified Classroom Contextual Gaps

Theme	**Subthemes/Cases**
ICT resources	Access to computers and related accessories internet access Up-to-date software
Pedagogical aspects	Teachers are limited to teaching and learning methods Classroom management approaches Teaching and learning aids, instruments and tools References and textbooks
Students aspects	Language of instruction barriers Lack of supports and motivation Backgrounds of mathematics and interest

During the FGD was revealed by the students that in the classroom there were no any mechanisms for utilization and usage of the ICT resources as was narrated:

> *….the schools is having only two mathematics teachers for form one to four; ….school is big with limited mathematics textbook; ….. Difficulty for teachers to deliver the same content likewise to almost eight hundred students whom will meet at different time in different classes.*

Certainly, other findings obtained through Likert Scale questionnaire for contextual classroom gaps on the aspects of ICT resources revealed the presence of negative skewness on availability of up-to date software, internet access and computer and related accessories as presented in Figure 2.

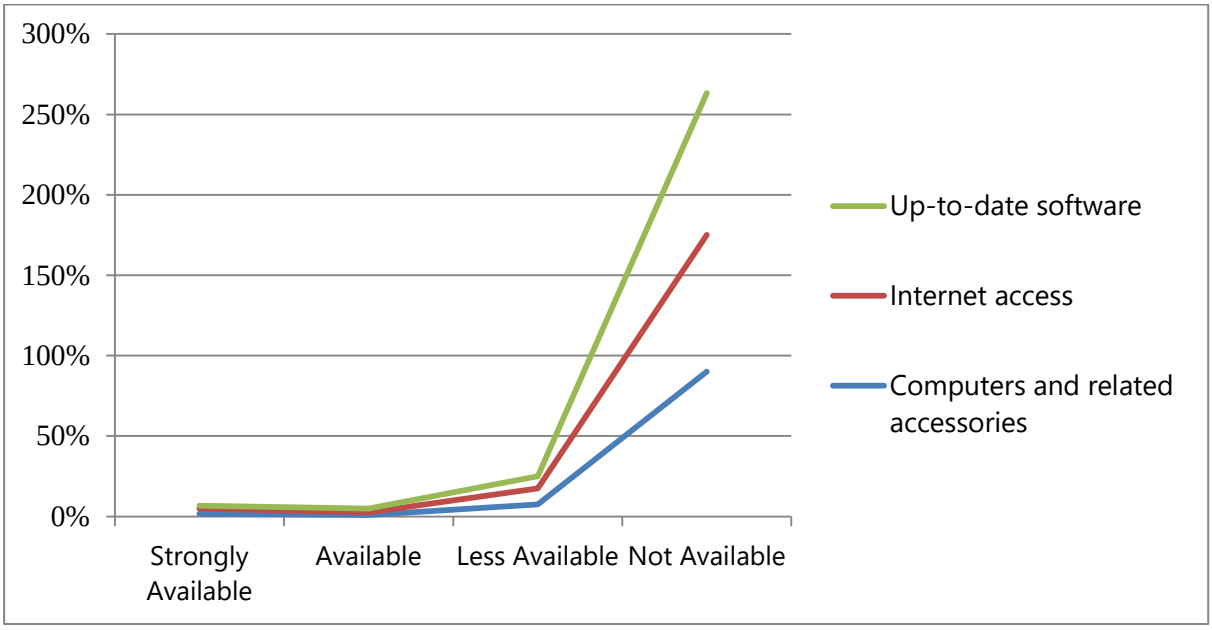

Figure 3: Classroom gaps on ICT resources

Outwardly, another findings on the utilization of mathematics pedagogical aspects as the classroom contextual practices gaps proved presence of differences in levels of utilization of students' engagement in teaching and learning methods, classroom management approaches, utilization and improvisation of teaching aids, instruments and tools, as well as accessibility of references and text books. The findings on the identified aspects delineated levels of the aspects to be available or highly available being between 0% - 21% as posed in Figure 3.

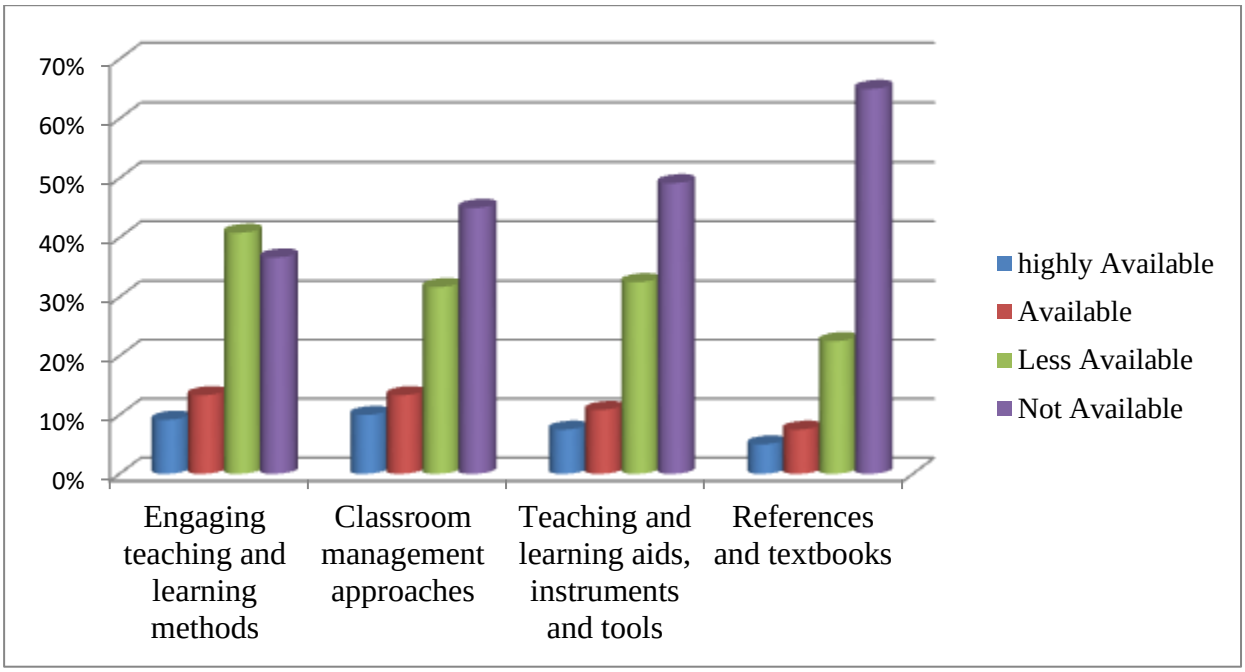

Figure 4: Gaps on methods, classroom management, teaching tools and textbooks

Afterward, the aspects of classroom contextual gaps was significantly assessed the levels of classroom contextual practices gaps in fostering the algorithms of mathematics in the areas of instruction

language being strongly supportive (20%) while not supportive (25%). Besides, during the FGD one of the form one students expressed the difficulties of mixing language and background as was narrated:

> *…. It is difficult to students to catch up mathematics as in seven years the concepts were taught in Kiswahili during our primary schools. …… as students we are facing two dilemmas one understands mathematics concepts the other is to the translation of the concepts in Kiswahili for easier grasping (F1 students in FGD).*

Likewise, the supports and motivations provided to students in learning mathematics outlined as strongly supportive (8%) and not supportive (52%); Further, on the backgrounds and interests in learning mathematics concept was discovered being strongly supported (20%), less supportive (32%) and not supportive (30%) as shown in Figure 4.

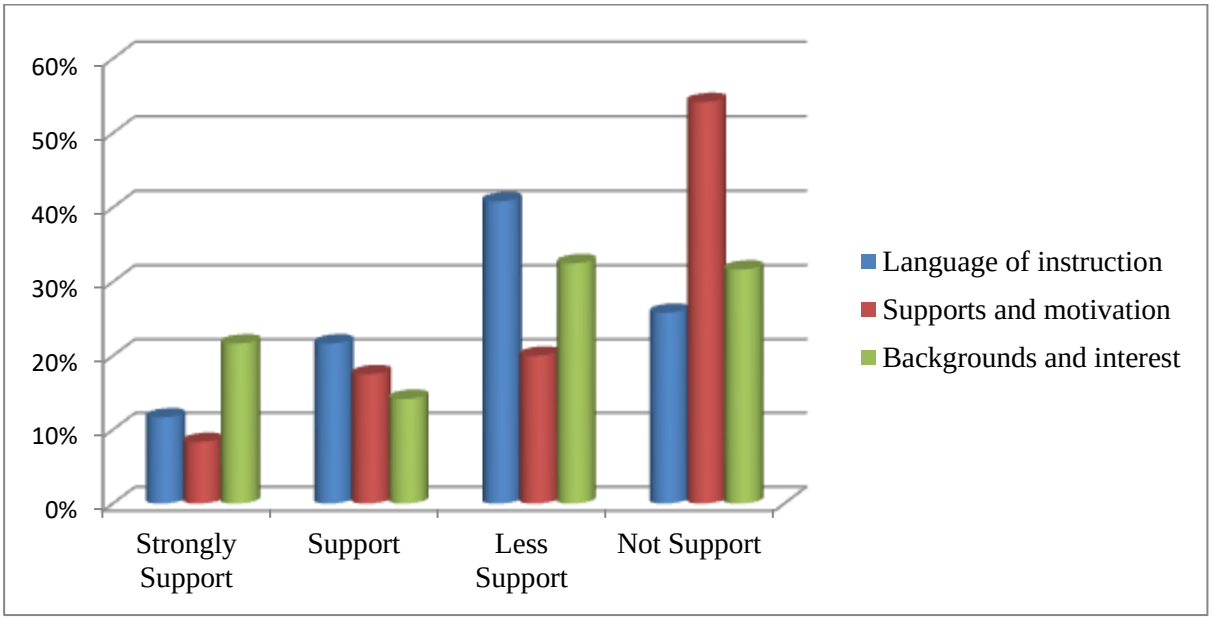

Figure 5: Gaps on language, support and motivation and background and interest

Based on the findings there are algorithms concepts gaps in different mathematics among secondary schools students. Students from selected community schools were marginally low performing in 22 mathematics topics being presented as algorithmic concepts gaps. However, the 4IR propagated foundation built on mathematics algorithms in creation and development of logics for creativity, critical thinking, collaboration and communication useful. Moreover, the designing, development and utilization of digitals and technology artifacts, tools, equipment and apps are highly depend on logics, creativity, innovation and critical thinking. Certainly, blending of mathematics algorithms, appropriate pedagogies that fosters students' engagement and technologies powered to influence and promote mathematical achievements (Kihwele & Mkomwa, 2022; Stephen, 2023). Consequently, the implication of the findings to today students as future human capital needs to be well oriented in the critical thinking that are built-in within mathematics algorithms competences with replication for technological advancements and innovations.

Likewise, the gaps in algorithmic of the students' non-accommodated mathematics concepts found in probability, three-dimensional figures, circles and spheres, vectors, and geometric transformation are essential in technologies invasion. Subsequently, Zhang et al. (2020) apprehended on algorithmic contents found within linear algebra and probability theories for enhancement of students' to acquire

logic, critical thinking, analytics and problem solving competences being valuable for sustainability in 4IR. Similarly, another implication was made to teachers as the main catalysts of classroom didactics to vein students-centeredness pedagogies in utilization of participatory, intuitive and inquiry approaches to support mathematics algorithms acquisition. However, the researcher suggested on capacitating students' to appropriately accommodate algorithms of mathematics concepts that open-doored 4IR workability in areas the areas of big data mining and science, computer graphics, and spatial reasoning.

Consequently, was found that students were also possessed gaps in the concepts of linear programming, matrices and transformation, radicals and exponents, coordinate geometry, statistics, algebra, logarithms, geometric transformation, sets, Pythagoras theorem, trigonometry, congruence and similarities, sequence and series despite of being essential in building logics, nodes and networking for modelling, automation of decisions, knowledge for discovering of data mining and machine learning. Yet, mathematics teachers are required to foster utilization of classroom strategies and techniques to uplift knowledge transferability, cognitive accommodation and long term storage of mathematics algorithms to outlay gaps experienced students (Li & Liu, 2022; Shu & Ye, 2023); fostered creation and development of sophisticated mathematical algorithmic tools, aids, theories and models (Pramod et al., 2021); extracting, identifying, accommodating and drawing reflective workable patterns from the complex datasets for developing predictive models and trends (Jiang, et al., 2023). Apparently, study insisted on the students to get exposure to the categorical mathematical algorithms required in the digital era (Abualigah et al., 2021; Hu et al., 2022; Bråting & Kilhamn, 2021 Meza, 2021).

Yet, the researcher argued on deploying the 4IR domains, emphasized on the need for clearing mathematics algorithmic gaps found in the raised concepts to boost students becoming the technologies invaders in developing and utilization of artificial intelligence, and machine learning by engaging into deep patterning algorithmic thinking. Also, the suggestions were made by scholars on utilization of Machine Learning (ML), Artificial Intelligence (AI), and big data analytics tools prompted enthusiasm in social-economic activities pertained onto the 4IR (Keleko, 2022; Chhillar & Aguilera, 2022). Despite the findings revealed students hold algorithmic mathematics gaps in concepts of numbers, functions and relations, accounting, area and perimeters but are essential for developing quantitative and analytical skills for realism of 4IR requirements. Similarly, was declared by , Prasad et al. (2022) that despite the identified gaps in algorithms for the concepts of numbers, accounting, group theories and elliptic curves but are essential because of possessing supportive nodes that are useful in developing the blockchain cryptography topologies.

Grounded on the findings the implications envisage the need for students to be equipped with relevant mathematics concepts for technologies innovation and mechanisms to encounter the shortfalls that hindered dealing with big and Meta-data sciences trends within the highly and safely 4IR practices application. Similarly, Zwilling et al. (2019) warned on the victimization of data and information through cyberattacks being evidently in the advancement practices brought by deployment of 4IR technologies. The implication made is on need of preparing today students to possess expatriation for sorting out cyberattacks based on its nature through restructuring the mathematics didactics to ensure appropriately attainability of cognitive, affective and psychomotor domains. Vividly, new digital era requirements enforced education systems and its components to change practices towards automation and the future works (Howard, 2019; Howcroft & Taylor, 2022; Fataar, 2020; Shu & Ye, 2023), henceforth leading the recommendations are to the mathematics teachers and students to change the classroom practices with useful, innovative, digital and technological integrative, motivational for enhancement and nurturing critical thinking, problem-solving, analytical skills, knowledge and competences for capturing the 4IR real-world requirements that are found in mathematics algorithms concepts.

Also, in the classroom contextual practices the gaps found were pertained in ICT resources, pedagogical and students' aspects with indicators affecting attainability of mathematics algorithm realism. Further, on the usability of ICT resources, there were unconducive and underutilization of technologies and digital accessories due to less accessibility of up-to-date software, internet, and devices. Based on that stance limited technology integration and exposures are implied thereby affecting multiple experiences in teaching and learning mathematics concepts. Subsequently, Tao et al. (2021) and Howard (2019) insisted on classroom resources investment for promoting the deployment of mathematics algorithms through utilization of technology based simulations apprehended for sorting the real life problems. Correspondingly, students with access to the ICT resources get envision digital opportunities through engaging into interactive learning activities, access to online resources, exposure into collaborative and exploration tools, supported and entertained by the digital games henceforward acquired multiple mathematics concepts algorithm realism.

Besides, implication made by the researcher on the marginal level of ICT resources available for mathematics concepts teaching and learning is to schools administrators, parents and other stakeholders to join forces to sort the deficiency to open doors for students to engage and developed digital literacy skills highly apprehended in 4IR. Accordingly, Pramod et al. (2021) insisted on utilization of automated sources and digital tools encompassed easier manipulation of volumes of big data that are frequently generated, developing and creation of advanced sophisticated mathematical algorithmic tools, theories and models. The replicative suggestions made are on the need for joining forces among different stakeholders to bridge the digital divide through prioritizing provision of ICT resources for students learning in the respective schools. Likewise, Stephen (2023) insisted on the need for addressing technological gaps found in classroom context to build future developers, designers and deposition of 4IR simulations. On the same vein, Howcroft and Taylor (2022) recommended on training today's students in digital, technologies tools and resources to capacitate today's students for the future works deployment. Moreover, recommendations are made are on the utilization and embracement of digital integrated supportive learning environment.

Based on the findings, pedagogies deployed in the classroom context were significantly limiting attainment of the mathematics algorithm realism. Based on the findings students were less exposed onto collaborative and engaging approaches, teachers hold marginal classroom management capacity due to class size, unconvincing improvisation of mathematics teaching aids, instruments, tools, and shortage in accessibility of references and textbooks. Apparently, the identified pedagogical gaps resulted students to develop subjectivism, anxiety and phobia towards mathematics as Amani (2023) and Jiang et al. (2023) expressed on the importance of reforming classroom contextual practices to capture, design, develop and deploy mathematics concepts as resource for deployment of social-technology related solutions. Nonetheless, Kihwele & Mkomwa (2022) addressed on the need to solve influential multiple psycho-cognitive experienced by students leading dislikes and became poorly in mathematics subject performance. Nevertheless, Stephen (2023) inspired the deployment of hampered mathematics concepts for students' performance through utilization of multiple teaching methodologies and multiple tools. Apparently, the implication was made on utilization of the blended mathematics pedagogies that embraced students' centeredness in stimulating inquiry-based approaches aligned with the demands of the 4IR. However, this study suggested on utilization of mathematics pedagogical approaches that foster students to develop digital literacy as well as changes intuitive adaptability brought by the rapid digital landscape found in 4IR.

Certainly, the textbooks and references shortages were disclosed by the findings implying that students difficulties in referencing the examples, workout procedures, class activities in the printed

material sources. In the current digital era the knowledge and competences found in Mathematics reference and textbooks are equipped students with systematic and logical methods for solving problems and performing computations (Pereira et al., 2023; Liu et al., 2023). Apparently, based on the findings the suggestion was made to schools and students to be equipped with reference and text books to outlay limitations for accessing knowledge sources from the diverse learning materials support understanding and exploration of mathematical algorithm realism.

Subsequently, despite the findings showing mixed support levels in motivation, background and interest among students, yet the language used in teaching was pertained to lead shortfalls in accommodating the mathematics algorithms concepts. However, there are well-defined languages and finite sequences of rigorous instruction found within Mathematics algorithm deployed to solve Mathematical problems (Dutta & Patel, 2022). Yet, Sapaty (2022) and Luger (2023) added that in 4IR era mathematics algorithmic language is built in the philosophy to empower students in solving problems through set of instructions useful in transforming capabilities of solving data set problems and programming. The implication made is that, students' had to be nurtured for enthusiastic and recognizes relevance of mathematics contents algorithm for their lives road mapped towards 4IR. The implication is made to students and teachers that despite the existing language diversity for effective communication, the focus should be on fostering curiosity, creativity, perseverance in problem-solving, provide constructive feedback, promote mind-set growth, motivation and self-efficacy development for acquisition of mathematics concepts algorithms that are demanded in 4IR. Finally, the recommendations are made to the mathematics teachers to deploy technologies integration, bring the real-life mathematics scenarios, design and implement the interactive activities, building supportive and inclusive classroom culture, provide personalized support, stimulate voices ad choices among students to build sense of belonging in mathematics classroom identified contents to empower students.

4. CONCLUSION

Based on the findings, the conclusion made by the study is that despite the mathematics algorithmic competences gaps found in different concepts being crucial for todays and future students. The raised gaps need to be well addressed to curb the challenges, ensure the success and sustainability in the digital era practices. Schools and teachers had to devote resources and time for exposing into innovative pedagogical methodologies focusing on participatory, intuitive, and inquiry-based approaches comprised of interactive learning activities; bridging the digital divide gaps through utilization of up-to-date digital and ICT resources in classrooms for students to develop digital literacy competences. Further, engaging students, effective classroom management, improvisation of teaching aids, language, accessibility of references and textbooks are crucial factors in promoting students' motivation, self-efficacy, and performance in mathematics.

The alarm made in the findings fosters the need for recommendations to the stakeholders in supporting schools, teachers and students with the necessary digital and technological tools, creating supportive learning environments that fostered creativity, critical thinking, collaboration and problem-solving skills fore-fronting accommodation of competences from Mathematics concepts algorithms contributing to invasion of technological advancements required in 4IR practices. Generally, suggestions are made on future research topics that are:

a) Integrating Mathematics Algorithms into Digital Tools and Simulations for enhancement of students' acquisition of 4IR competences.
b) Enhancing Students' Digital Literacy Skills through Accessible ICT Resources in Mathematics learning

c) Investigating the Impact of Participatory, Intuitive, and Inquiry-Based Pedagogies on Students' Understanding of Mathematics Concepts in the Fourth Industrial Revolution.

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