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Secondary school teacher's conception and reflection of computer programming with Scratch

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Abstract
The present study explores teachers' conception and reflection of computer programming with a Scratch in terms of technological and pedagogical aspects. A mixed research approach specifically sequential explanatory research design was used to collect quantitative and qualitative data. The population was comprised of two hundred and four in-service Mathematics, Chemistry, Physics, and Biology teachers from Kayonza district, Rwanda. However, only 34 were randomly selected to participate in the study. An achievement test and structured interview were used to collect quantitative and qualitative data, respectively. The quantitative data obtained from pre- and post-tests were analyzed using a paired *t* test, and the data from the interview was analyzed by descriptive, and interpretive analyses. It was revealed that secondary school teachers have a respectable conception and constructive reflection of Scratch programming once attending scratch training. Quantitative findings showed that there was an important difference in the mean among pre- and post-tests with 0.171 learning gain and an effect size of 0.53 ($df = 33$, $p < 0.05$). It was also revealed that Scratch is an operational instructional tool for teaching and learning Mathematics and Sciences. Furthermore, teachers articulated progressive views of using scratch in teaching and learning Mathematics and Sciences as it supports them to visualize abstract content, improves students' interest and impetus, critical thinking, and problem-solving skills, and acts as an assessment tool.

Keywords Scratch · Programming · Reflection · Conception · Pedagogical tool

1 Introduction

Computer programming thrived to increase most of the features of our civilization, answer people's needs, and be flexible to present and upcoming technology [20]. Utilizing computer programming enhances the computational thinking of students [30]. Teachers at dissimilar stages and from various subjects use computer programming to advance teaching–learning and aid students to improve skills [12].

Scratch is a programming computer software that allows users especially children between the ages of 8 to 16) to learn computer programming while working on personally meaningful projects, such as animation, stories, music videos, science projects, tutorials, and games [24]. Scratch also is the application used to create projects containing media and scripts. Scratch consists of three parts, such as block, script, and Stage. Blocks include block palettes divided into groups within themselves; script the area is where programming is implemented, and the stage displays sprites [40]. The latest version of scratch is

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Scratch 2.0 which was introduced in May 2013. This version is the best and users are recommended to you it, because this version makes it easier for people to share their projects, take a look at each other's projects, and adapt them or remix them) to create or polish your project [28]. The projects designed can be shared online community with an open-resource link.

Scratch is an extremely useful tool that can enable teaching unclear concepts in any subject [26]. Thus, Scratch is a tool that Mathematics and science teachers can use to visualize and complement their teaching. Programming through Scratch is a method used to elaborate scientific perceptions [39]. Scratch generates educational and engaging content, put on and visualizes mathematically, and envisages the concept. Scratch advances learners' digital knowledge, resourcefulness, and creativeness, promote knowledge retention, encourages critical intelligent, and elucidates complex problems [37]. It was found that Scratch has an affirmative influence on educating mathematics and sciences, the research carried out by Noftiana et al. [27] indicated that utilizing scratch in teaching physics aids students to comprehend electric dynamics and they become involved in Scratch animation. Scratch supports the student to check themselves physics model and permit them to apprehend more physics [33].

Weber and Wilhelm [38] indicated that the usage of programming in physics instruction has a constructive impression on students' conceptual understanding, critical thinking, and intensification interest in physics. Scratch is a valuable tool that supports the student to teach the difficult mathematical concepts [6]. It is expressed that the use of Scratch allows mathematics to be more enjoyable and interesting to learners during the learning of geometry [16]. Via Scratch teaching, exponential function, a linear function, quadratic equation became easier. The study of [22] revealed that a Scratch is a convenient tool in teaching the chemistry of the Bronsted–Lowry acid–base model.

Active learning is essential for both internal and external processes, because it shapes thinking [36]. An effective educational experience requires both deep and meaningful understanding of the subject matter. When students successfully acquired procedures methods theyfor could look a resolution of conceptual problems faced in their learning process [23]. Mathematics and sciences are meaningless and incomprehensible for learners if the learners are unable to relate them to their lives [19]. Mathematics and science subjects need reflective thinking. Reflective thinking is needed to understand and solve the problem and increase students' interest. Softwares design, reflective thinking strategy have a positive impact on the improvement of learning performance of the students especially those ally who are less successful [20].

The way mathematics teachers present activities to the learners make them hate or like mathematics. The research showed that there is the persistent problem of grasping mathematics and sciences concepts due to inappropriate teaching methodology [18]. The steps for the solution of the problem in the programming process. The research also showed that insufficient in-service training in the transition of new programs and number of science and technology teachers' taking an active role in the preparation of the programs of mathematics and science teachers as challenges that face them in their work [21].

2 Research questions

(1) What is the teacher's understanding toward the usage of Scratch as an instructional tool in mathematics and sciences instruction process?
(2) How do teachers reflect on the effectiveness of Scratch in mathematics and sciences instruction?
(3) What are teachers' insights towards the application of Scratch as an educational tool in Mathematics and Sciences teaching?

Therefore, the following hypothesis are formulated to respond the first research question.
Ho: There is no significant conception of teachers on programming with Scratch after the course before.
H1: There is a significant conception of teachers on programming with Scratch after the course before.

3 Methodology

3.1 Research design

The current study used a mixed-method sequential explanatory research design, where qualitative and quantitative approaches were used to gather and analyse data. A sequential explanatory research design implies collecting and analyzing quantitative and then qualitative data in two consecutive phases within one study [17]. A combination of

quantitative and qualitative methods is useful to complement each other, allow a robust analysis, and taking strength all methods than the other [7].

In the mixed-method sequential explanatory research design aids the researcher to elaborate or clarify the findings from one method with the findings from the other technique [25]. In this study researchers started by collecting and analysing quantitative data, whereby pre-test was collected first to see teachers' prior knowledge of computer programming from scratch, after conducting the pre-test researchers train 34 mathematics and science teachers about computer programming in the period of 3 months during the weekend. After training all participants did a post-test to see if their understanding was improved. After analyzing quantitative data, the researcher collect qualitative data via structured interview to get educator's reflection after being trained and utility of scratch in mathematics and sciences instructional process. The qualitative data was gathered in another phase to clarify the quantitative data gotten in the primary phase.

3.2 Population

The population is a regular cluster of all components in which research results need to be used [9]. However, the population of this study was two hundred and four in-service mathematics, chemistry, physics, and biology teachers of in the District called Kayonza in the province of East, in Rwanda Country.

3.3 Sample and sampling procedure

A sample stands for an illustrative unit of population [34]. Gowda et al., [14] asserted that a sample is a symbolic of the population, keeps time, and yields findings that are precise. In this study, we used a sample of 34 in-service teachers of Mathematics, Chemistry, Biology, and Physics from the ordinary level in Kayonza district, Rwanda that were randomly selected. This sampling technique is suitable, since all members have an equivalent chance to contribute in the research [35]. In this study all participants got an equal chance to participate the study, the researchers made a list of all participants then a participant was selected at a sampling interval of six. The sampling interval was obtained by dividing the population size by the desired sample size which is equivalent to 6th.

3.4 Data collection tools

3.4.1 The achievement test

The test is useful to describe the level of appreciative of understanding and concepts [32]. In this study, in cooperation pre- and post-tests were used to gather data. A pre-test was utilized to check the teacher's previous knowledge in advance of joining Scratch training, while a post-test was used to check whether the teacher's knowledge of Scratch was improved after joining training scratch in Mathematics and Sciences instructions. The training aimed to improve quality of teaching mathematics and sciences, this done by 4 h per week during the weekend in the period of 3 months. Both pre- and post-tests were scored over twenty scores.

3.4.2 Structured interview

A structured interview is an instrument of data collection utilized to gain the individual sight, views, and emotional state of participants [3]. A structured interview is useful, because it provides Consistent data that can be compared across a number of respondents [5]. In the present study, the structured interview was utilized to examine teachers' reflections after joining scratch training and its utility in Mathematics and Sciences instruction.

3.5 Data analysis

During the data analysis, the qualitative and quantitative analyses were used. The quantitative data were analyzed by the help of descriptive and inferential statistics. On the other hand, the descriptive analysis like minimum, maximum, mean, and standard deviation were utilized, whereas inferential statistics paired *t* test, Spearman correlation were used. Paired *t* test matches the mean of a single group tested at two dissimilar points in time [2]. The used paired *t* test helped to was compare the means of performance in advance and after being trained at 95% confidence level. Thus, this is one group pre- and post-test design and it is appropriate among quasi-experimental designs. By the help of paired sample *t*

Table 1 Pre- and post-test results found through a descriptive and inferential analysis

Tests	Mean	Std. deviation	Min	Max	*p*	*d*
Pre-test	14.45	5.44	13	16	0.001	0.53
Post-test	17.21	4.48	16	20		

Table 2 Correspondence analysis of pre- and post-tests

Tests	*N*	Correlation	Sig
Pre-test and post-test	34	.575	.0171

test, the author are able to determine whether training has improved educators' knowledge or conception after scratch training. The analysis of the qualitative data was performed through the interpretive analysis. It was affirmed that the interpretive analysis helps the investigator to get insight exactly on how participants enjoyed a given process [1].

3.6 Reliability and validity

During the research, it is important to check validity and reliability of the instruments. It was argue that validity in the research is to measure what is expected to measure [31]. To confirm the validity of the research tools, interview protocol, and achievement test were tested and approved by the professional in the research in education at the University of Rwanda, College of Education (UR-CE). The tools were adjusted according to their remarks and approval. Reliability stands for the stability and consistency of the data [4]. Ten chemistry teachers piloted the achievement test used in this study. This was done to make sure the reliability. To confirm the internal stability of test items, a reliability coefficient was utilized by the means of the Split-Half reliability technique. Two clusters of educators were created, each cluster was comprised of six, and achievement test items were divided into halves. Single cluster did odd questions, whereas the further cluster did even questions. The reliability coefficient amongst the two clusters was performed and got 0.81 which is great.

3.7 Ethical issues

During the present study, the researcher gained research authorization from the learning officer and the participants clarified the aim of the study. The participants accepted to sign agreement and contribute in the research willingly. The norm of secrecy and privacy were obeyed.

4 The results and discussion

4.1 Teachers' understandings on the use of scratch in Mathematics and Sciences instruction process

The following part discuss the instructors' score on pre- and post-tests. The results in Tables 1 and 2 were found through a descriptive as well as inferential analysis. Tests were practical and marks were scored out of twenty grades. The findings in Table 1 displays the mean of marks that was found to be 13.53 with the standard deviation of 0.21 obtained in the pre-test and improved to 18.38 with a standard deviation of 0.42 found in the post-test. Maximum marks found was 16 in the pre-test that was increased to 20 in the post-test. Minimum marks was 13 in the pre-test which was improved to 16 in the post-test.

The results obtained through paired *t* test revealed that there is an important difference from the pre- to post-tests ($df = 33$, $p = 0.001$) with effective size (d) of 0.53. Thus, the p value (probability value (p) of difference was lesser than predictable 0.05 (confidence level of 95%). Consequently, the findings revealed that educators have a pronounced conception of using scratch in Mathematics and Science instruction after joining scratch training. The correspondence analysis of pre- and post-tests in Table 2 indicated that there is a good correlation of 0.515 after joining scratch training.

These results in Table 2 are in covenant with former authors. Sáez-López et al., [29] revealed that there is an important difference within pre-service teachers' understanding after joining scratch training. Regarding [16] revealed that the usage of scratch has a progressive correlation with the learners' overall school achievement and indicates that there are no differences in achievement amongst boys and girls.

The found results are in line with García-Gutierrez and Hijón-Neira [13] who indicated that scratch has a helpful and important degree of teaching and learning. Scratch is a tool that has endorsed mathematics to be enjoyable to students. The results of Budak et al., [8] originate that using scratch has a progressive influence compared to past teaching approaches. Besides to probe teachers' understandings of programming with a scratch in Mathematics and Sciences instructions during training session, teachers develop mathematics and science scratch projects related to the subject they teach Chemistry, Mathematics, Physics, Biology. The four best project selected in mathematics, chemistry, physics and biology are shown below. The link with the screenshot of the developed project can be found below.

Figure 1 shows the example of the designed project done by a chemistry instructor (water cycle): link of the project and screen demonstration are below. https://scratch.mit.edu/projects/600905581/

Figure 2 shows the example of the project planned by physics instructor (newton law), the link is https://scratch.mit.edu/projects/631667157/ and the screen shoot is found below.

Figure 3 shows the example of the project planned by biology instructor (Ecosystem), the link is https://scratch.mit.edu/projects/579176305 and screen shoot is found below.

Figure 4 shows the example of the project designed mathematics educator (drawing Geometric figures), the link is https://scratch.mit.edu/projects/582247957/ and screen shoot is found below.

4.2 The Teacher's reflections on the effectiveness of scratch as an educational tool for Mathematics and sciences instructional process

To examine teachers' reflections about the effectiveness of Scratch as an educational tool in Mathematics and Sciences instructional process, The teachers' opinion and sights were obtained by interviewing them. An interview protocol was comprised of two open questions look at the following (Box 1). To obey the confidentiality of participants. The following coded to name teachers T 01 up to T 34 were used.

Box 1

Are you equipped to use Scratch in your upcoming teaching? If yes, what will it help you to increase?
In your opinion, what are the significance of Scratch in Mathematics and Sciences instructions towards students' understanding?

The interviewed teachers 95% agreed that they were going to incorporate Scratch into their teaching and assumed that it will support them to improve their teaching. In addition, 5% of interviewed teachers expressed that they need further trainings. One teacher T007 said" *I will use Scratch in my instruction process, because it will help me to advance assessment approach".* One more teacher (teacher of biology) T14 said that "*Scratch will support me to increase my teaching by demonstrating abstract concepts*". An instructor of chemistry stated," *by programming with scratch, I am equipped to produce*

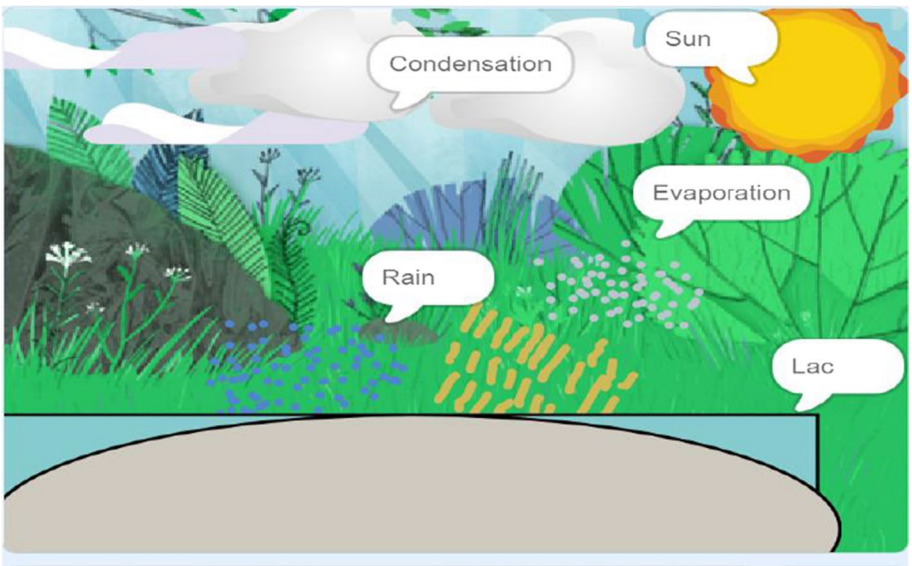

Fig. 1 Screen shot of the project designed by chemistry teacher

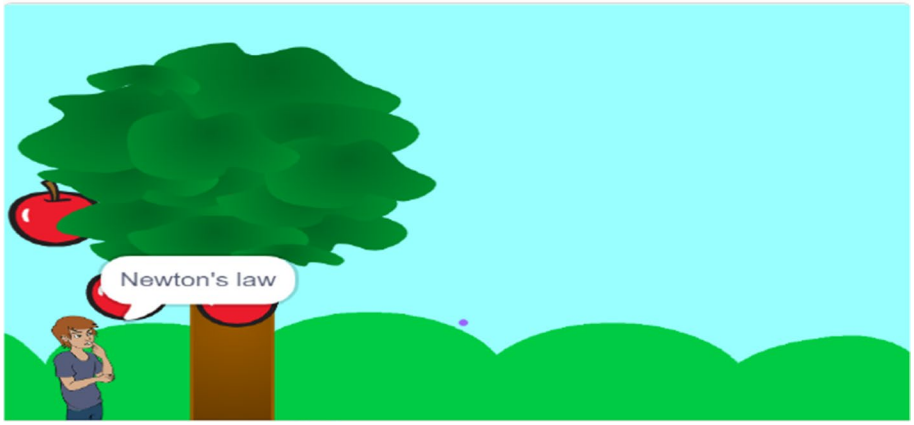

Fig. 2 Screen shot of the project designed by physics instructor

Fig. 3 Screen shoot of the project designed by biology teacher

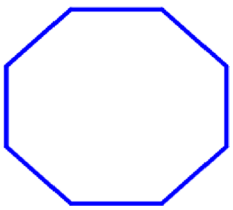

Fig. 4 Screenshot of the project designed by mathematics teacher

the animation," (T003) said. All instructor 100% approved that they are going to utilize scratch in their instruction and will endorse other teachers to use it to encourage students to learn and love Mathematics and Sciences, rises student's critical thinking skills and achievement, rapid problem-solving skills of students, and aids students to recognize abstract content. *A chemistry teacher T030 said that" Scratch is significant in my teaching, because by Scratch training quality of planning and providing lesson was value-added".* Another physics teacher T022 described that*" programming with Scratch had a helpful effect on my teaching profession".* The Mathematics and sciences educators informed that Scratch is meaningfully essential to deliver a lesson, evaluate content, rise analytical skills, understanding concept, advance problem-solving, and acute thinking skills.

The above findings are the same with the results of Fagerlund et al., [11] demonstrated that programming using scratch rises computational knowledge and problem-solving abilities. Furthermore, the use of Scratch programming upturns students' conceptual understanding of content [27]. According to Gutiérrez and Zapatera Llinares [15] identified that Scratch works as a demonstration technique, supportive learning and gamification, and assessment instrument in teaching line function and quadratic function. It was also found that Scratch is an encouraging tool and support the teacher to deliver lesson and make the subject visible [39].

4.3 Teachers' perception towards the utilization of Scratch as a pedagogical tool in teaching and learning mathematics and sciences

To investigate teachers' perception of using Scratch as a pedagogical tool, one open-ended question in the interview was used by all participants. The guided interview question is found in Box 2.

Box 2

Is Scratch a suitable instruction tool for teaching Mathematics and Sciences? How

The interviewed teachers (100%) approved that a Scratch is an advantageous tool in teaching Mathematics and Sciences. The causes are: T 004 said that *"by Scratch programming, my improvisation capacity was increased"*. One more teacher clarified that "*by Scratch programming, my skill to produce content that can improve students' attention and motivation has enhanced"* T 16. T 008 stated that Scratch facilitated him to generate animation for active teaching biology subjects. Seven instructors T 01, T 13, T 06, T 11, T 18, T 05 & T 19 stated that "*Scratch is an appropriate tool in Mathematics and Science instruction process, because it improves critical thinking skills*". T 15 clarified that "Scratch *is a proper tool for visualizing abstract concept". Scratch is a good assessment tool in Mathematics and Sciences.* T 02 said.

From these teachers' ideas, it was found that a Scratch is a right tool in teaching Mathematics and Science as it aids teachers to produce digital content, enhance students' attention, awareness and motivation, produce animation, evaluate content, and visualize abstract content and advance critical thinking of learners. The found results are in agreement with [30] who revealed that pre-service instructors have a constructive perception and approved that Scratch is stress-free to use in instruction of mathematics. The study carried by Choi, [10] on Korean pre-service instructors showed that teachers have a pronounced intention of using scratch in further teaching.

5 Conclusions

This study tended to examine teachers' conception and reflection of computer programming with a Scratch in Mathematics and Sciences instructional process. The findings of the study revealed that programming using Scratch has a constructive effect on Mathematics and Sciences instruction. The paired *t* test results indicated that there is an important statistical difference in teachers' marks after joining scratch training. Mathematics and science teachers' Scratch projects revealed that scratch is an active educational tool in Mathematics and Sciences instruction. Interview outcomes discovered that Scratch enhance students' attention and motivation, improves students' knowledge and critical thinking skills, makes the abstract concept visible, works as an evaluation tool, and improve students' achievement and problem-solving abilities.

6 Future consideration

The current study found stimulating results. Nevertheless, the sample was not big. The researcher indorses future studies use a big sample. Upcoming studies are required to examine the usefulness of Scratch to students' conceptual understanding and school performance compared to the other teaching approaches. Further works will discover students' conception of programming from Scratch using two groups, control and experimental group.

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Author contributions AI: conducting training, data collection, data analysis and writing final manuscript.EN: Working on the provided comments.JCH: grammar checking. All authors read and approved the final manuscript.

Data availability The data sets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate The researcher obtained research permission from ethical approval committee of Kayonza district and educational administrator. The participants have explained the purpose of the study. All participants were agreed to sign consent and participate in the research voluntarily. All participant were aged between 24 and 42. The principle of anonymity and confidentiality were respected.

Competing interests The authors declare no competing interests.

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