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# Effect of context-based approach on students' scientific reasoning on heredity concepts

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**ABSTRACT**

This study aimed to examine the impact of a context-based relating, experiencing, applying, cooperating, and transferring (REACT) strategy on the scientific reasoning (SR) abilities of tenth grade students. A mixed-method approach and convergent embedded experimental design were used. One hundred thirty-one students participated in the study in three groups. REACT strategy of context-based instruction and conventional instruction integrated with context-based activities was used to teach treatment group 1 (TG 1) and treatment group 2 (TG 2) students, respectively. The students in the comparison group (CG) were taught conventional instruction. The data collected using two-tier multiple-choice tests, observation, and semi-structured interviews were analyzed using one-way ANOVA and descriptive analysis. The result showed that there were significant mean score differences between TG 2 and the other two groups in favor of TG 2. Nevertheless, there was no significant difference between TG 1 and CG. This implies that when conventional instruction is integrated with a context-based activity, it has a significantly positive effect on students' SR skills compared to using a context-based REACT strategy or conventional instruction alone.

**Keywords:** context-based approach, scientific reasoning, REACT strategy, heredity

## INTRODUCTION

Many countries around the world are focusing on the need for a well-prepared workforce for the twenty-first century, which entails students learning not only science content but also advanced transferable reasoning skills (National Research Council [NRC], 1999). According to NRC (1999), the most important goal for biology curriculum is not only content acquisition and comprehension, but also reasoning and other skills. Scientific reasoning (SR) is related to cognitive abilities such as critical thinking and reasoning. SR is the process of producing scientific knowledge through evidence-based reasoning for making sense of phenomena, events, and processes (Lawson, 2004; Schen, 2007). The development of these skills will better enable students to handle open-ended novel situations and design their own investigations for successful management of real-world problems in society beyond the classroom (Bao et al., 2009a; Han, 2013). Therefore, SR is the heart of scientific knowledge generation and is indispensable not just for future scientists but also in today's knowledge-based society (Jufri et al., 2016). Fostering SR is highly relevant for science education and lifelong learning from the elementary through college levels of education (Bao et al., 2009b; Engelmann et al., 2016; Jufri et al., 2016).

### Review of Related Literature

Literature shows that students perform poorly in SR at different levels of education, from primary to tertiary. International testing over the last decades has revealed that students in numerous nations do not have an adequate grasp of conceptual scientific knowledge or SR skills that allow them to construct arguments based on scientific evidence (OECD, 2014). For example, Saad et al. (2017) revealed that Malaysian students' accomplishments are low to medium level, and they are incompetent to relate the concepts of science and socio-scientific issues like the environment, medicine, health, and genetic engineering. After graduating high school through transmission teaching, students join university and university students in Thailand also mostly reason unscientifically (Piraksa et al., 2014). On the other hand, internationally, more countries demonstrated relative strengths in knowing science (i.e., recalling, recognizing, defining, and describing) than in applying scientific knowledge and reasoning (Bao et al., 2009b; Osborne, 2013).

It is crucial that teachers master SR since their classroom strategies play a crucial role in students' development of this skill. In a province of Ethiopia, Dawit (2022) investigated the capacity for SR of teacher educators, schoolteachers, and prospective teachers. The author reported that majority of the participants (86.00%) were intuitive thinkers, indicating that they had a generally low degree of reasoning ability. The author compared the reasoning skill of participants, which teacher educators had better reasoning skills than schoolteachers, who in turn had superior skills to prospective teachers. The majority of prospective teachers (94.80%) and schoolteachers (88.60%) were found to be intuitive thinkers, while teacher educators were found to be equally split between transitional and intuitive thinkers. As important as focusing on SR skills while teaching, Mulugeta et al. (2021) confirm that science and mathematics teachers in Ethiopia do not focus on it.

Teachers' low reasoning skill and lack of concern while teaching science subjects could be one reason for students' low reasoning skill. Ethiopia's third national learning assessment MoE (2017) showed that students have low achievement in science subjects. The content of the achievement test is more knowledge-based. Several empirical studies have shown that learning the sciences does not always result in improved SR. For example, Bao et al. (2009a) compared American and Chinese university students' physics knowledge and SR. They have found that although Chinese students performed much better on the science knowledge test, their performance on the science reasoning test was low and similar to that of their American peers. This implies that Ethiopian students might have low reasoning skills; hence they achieve below-standard in knowledge levels tests.

Literature shows that traditional methods of teaching, an overloaded and less relevant curriculum, and low-level activities are some possible reasons for low reasoning skills. SR skills are developed in the classroom by doing activities, but they are not inherently learned by the student, and rigorous scientific education is not enough. It is not what is taught, but rather how it is taught, that makes the difference in student learning of higher-order abilities in SR (Bao et al., 2009a). The current style of content-rich STEM education, even when carried out at a rigorous level, has little impact on the development of students' SR abilities (Bao et al., 2009a). Because the method used mostly emphasizes more on remembering and practicum. This condition shows the urgency to implement SR during the learning process. Hence, reasoning ability is not an innate ability; rather, its development is influenced by the curriculum and teaching methods used by teachers, among many other factors (Adey & Csapo, 2012).

According to Cimer (2012), there are three reasons that make biology difficult to learn:

(1) there are many concepts and biological events that cannot be seen with the naked eye because they are too abstract or not visible,

(2) students are "forced" to memorize biological facts in order to learn them, and

(3) some students mentioned that the time available to study biology was insufficient.

Biology learning becomes more meaningful when students observe the object they are learning directly. However, not all biological symptoms and phenomena can be observed directly, especially in physiological processes that occur in the bodies of living things, one of which is heredity. Heredity is one of the biology topics considered difficult by students (Cimer, 2012). As a result, students' understanding of the material they learned became low. Similarly, Haskel-Ittah et al. (2020) have shown that genetics is challenging for both teaching and learning for several reasons. First, many of the core entities and processes in genetics, particularly molecular genetics, are unfamiliar to high school and university students since they are far from their day-to-day experience and full of new, difficult terms. Second, genetic phenomena transverse multiple levels of organization, and reasoning across these levels is challenging for students. A third challenging aspect of genetic phenomena that has not received much attention in genetic education research is the complex interactions between the environment and genetic mechanisms in the development of traits.

According to Saad et al. (2017), in order to produce excellent reasoning students, the discussion of socio-scientific issues (SSI) should be emphasized so that students are not only able to find answers to problems and solve them but can also practice in their daily lives. OECD (2014) recommends the use of authentic practices, which include model-based pedagogy, to improve student reasoning abilities. Some suggest using modeling to facilitate SR (Adey & Csapo, 2012). Relating students' experience and concepts can help students better understand biological concepts. Teaching should be based on the students' experiences and allow for the solution of real-world problems (Gilbert et al., 2011).

Changing the mode of instruction can have a positive impact on student reasoning. Teaching should be based on the students' previous knowledge, and the connection between the experience of students and biological concepts can help students better understand biological concepts (Jufri et al., 2016) and reason well (Bao et al., 2009b). Therefore, the researchers were interested to design context based approach to improve students' SR skill. We compared context-based approach with conventional teaching method and combined teaching (a mix of context-based activities and conventional instruction).

A context-based approach begins by teaching about the student's everyday experiences and interests. The constructivist approach plays a great role in context-based teaching (Bennett et al., 2005; Gilbert, 2006). The majority of studies conducted on context-based learning address the social constructivist view on learning (Gilbert, 2006; Parchmann et al., 2006). This study focused on biology learning that draws on students' everyday life experiences. Central to this study is the contextualization of a delegated biology curriculum, which is interpreted and enacted in ways that link the concept of biology with students' real-world local contexts. This helps students find meaning in the learning process by making connections between the concept and the phenomena or activities they encounter in their everyday lives in the local context. Hence, learning takes place within a social, cultural, and local context from which students draw their everyday life experiences. To avoid isolating school from society and everyday life, the researcher adopted the social and sociocultural constructivist learning theory as a tool to guide the present study.

A significant number of context-based intervention studies in science education have been reported in science, chemistry, and physics in relation to motivation, interest, and achievement. Ethiopia is known as a multilingual and multicultural nation, and Ethiopian culture and context are also different from other countries; however, empirical studies on the impact of context and culture-oriented activities in the teaching-learning atmosphere on students' SR are yet to be explored.

One solution for better understanding is to use pedagogies, which are efficient in engaging and motivating students to learn science by making the content context based. Undeniably, 'quality of pedagogy' should be a concern to bring quality education in each and every classroom (Panigrahi, 2013). Despite the Ethiopia education policy promoting learner-centered instructions, research findings reported that, the content led and overloaded curriculum does not endorse the implementation of active learning methods in the classroom (Meskerem, 2017). As Joshi and Verspoor (2013) mentioned, among other pressing problems, the overloaded curriculum nature in Ethiopia is accounted for the implementation of unsuccessful instruction, which is also one of the consequences for student's poor performance in reasoning. In Ethiopian context, the effort to make learning context-based is minimal (Gebeyaw et al., 2021) and, as a result, students find no meaning or relevance in what they learn. Scholars suggest that science learning, in whatever method delivered, should be context- and culture-based (Bennett et al., 2006; Gilbert et al., 2011). To our knowledge, no study has been conducted on students' levels of SR skills in Ethiopia using context based approach as an intervention. In this study, the researcher was prepared the intervention material on the bases of students' day-to-day experiences and the lesson delivery also guided by relating, experiencing, applying, cooperating, and transferring (REACT) strategy. Since finally, the researcher believes that learning biology concepts are affected by social practices, hence, incorporating culture-based instruction would motivate and engaged students' during the lesson implementation. The research questions to be addressed in this study were, as follows:

1. What is the difference between the two treatment groups (TGs) and comparison group (CG) on students' SR skills after intervention?
2. What is the level of SR skills of the two TGs and CG students?

## METHODOLOGY

### Design

The researchers used both quantitative and qualitative data to examine students' SR skills intensively and extensively. A mixed-methods experimental (or intervention) design occurs when the researcher collects and analyzes both quantitative and qualitative data and integrates the information within an experiment or intervention trial. Hence, a convergent embedded quantitative dominant mixed-method experimental design guided this study, and qualitative data was used to support the quantitative information obtained from the participants (Creswell & Plano Clark, 2018). In a convergent mixed-methods design, regardless of the emphasis being placed on each of the qualitative and quantitative strands, the overall intent of the researcher is to converge or compare the results from the two databases (Creswell & Plano Clark, 2018).

For quantitative research design, a non-equivalent multiple group quasi-experimental pre-/post-test design was used to compare the understanding of students who were exposed to a context-based teaching approach with that of those who experienced conventional teaching approaches. Although randomization of subjects to treatment was not applicable in a quasi-experimental research design, schools and intact classes were randomly assigned as treatment and CG. The design has one CG and two TGs. Accordingly, treatment group 1 (TG 1) was taught with a context-based REACT strategy, treatment group 2 (TG 2) was taught with context-based activities integrated with conventional instruction, and CG was taught with conventional instruction.

### Population and Sampling Procedures

The population of the study comprised all grade 10 students in government secondary schools around Debre Birhan, Ethiopia. A simple random sampling technique was used to select schools and subjects for participation in the study. The study involved 131 10$^{th}$ grade students (46 boys and 85 girls) in the selected government secondary schools. Under unit 2 of the 10$^{th}$ grade textbook, the intervention covered four topics: chromosome and gene, mitosis and meiosis, Mendelian genetics, and heredity and breeding of heredity. In the syllabus, it is indicated that the unit needs 16 periods to be completed. Hence, the intervention took about six weeks in the first semester (three periods per week).

### Data Collection Instruments

Data were collected using various data collection tools in order to answer the research questions of this study. The data gathering tools of this research were the two-tier multiple-choice scientific reasoning skill test (SRST) developed by the researcher and administered as a pre- and post-test, semi-structured interviews, and classroom observation. An interview was conducted during and at the end of the intervention, and classroom observation was made throughout the intervention. The test was developed using the steps used by Treagust (1988) to develop a two-tiered test. Three questions were adapted from (Tsui & Treagust, 2010). To collect data for further review and improvement and to determine the reliability and discrimination of the instruments, one hundred grade 11 students (36 boys and 64 girls) participated in a pilot study; hence, the content was covered in their grade ten learning.

Now a days assessment instruments composed of two-tier multiple choice (TTMC) items are widely used in science education as an effective method to evaluate students' sophisticated understanding including SR (Bao et al., 2018). The researcher used multiple choice questions with two tiers and the pair scoring method to assess students' reasoning levels in this study. The maximum score was 37 and the minimum was zero for SRST.

The mean difficulty level of SRST was 0.30, which shows that items are difficult for students (Mehta & Mokhasi, 2014). The discrimination index of SRST ranges from 0.23 to 0.48. One of the commonly used ways of calculating internal consistency reliability for dichotomous items is Kuder-Richardson formula 20 (KR-20) analysis. The reliability of SRSTs was investigated by calculating an internal consistency measure, KR-20. Tsui and Treagust (2010) determined that the reliability coefficient of SR was .69, which is adequate for a two-tier test.

### *Instructional strategies*

The intervention took about six weeks (three periods per week). It covered four topics: chromosomes and genes; mitosis and meiosis; Mendelian genetics; and heredity and breeding. It was implemented by the schoolteachers, who were trained for two days in a workshop facilitated by the first author on how to implement the developed context-based teaching materials. The teacher who taught CG was not trained but used the usual textbook. In TG 1, a context-based REACT strategy was used. The context presented was a social circumstance, which is explained by Gilbert et al. (2011) as model 4. There are five phases in this strategy:

(1) relating,

(2) experiencing,

(3) applying,

(4) cooperating, and

(5) transferring.

*Relating* is learning in the context of one's life experiences or preexisting knowledge. For example, for the topic of heredity and breeding the activity used was:

> "Beza is a grade 10 student, and she has the best sheep to support her parents by gaining income. Many people asked Beza to sell her sheep to them because her sheep are twin givers and give a large amount of meat. Are there animals known as best and poor in your house or your neighbor's? What characteristics of these animals make them the best? How can you increase the number of these animals? Can you increase the quality of poor animals to make them better? How?"

*Experiencing* is learning by doing, or through exploration, discovery, and invention. For example, for DNA topic students were exercises

> "the process of DNA replication by using letters of nitrogen bases (A, T, G, and C) and clearly identify which nitrogen bases combined together based on fitting shapes like that of a socket."

*Applying* is learning by putting the concepts to use. Applying is a contextual teaching and learning strategy that develops a deeper sense of meaning and a reason for learning. For example, for Mendelian inheritance in human the activity used was:

> "Almaz has blue eyes, and she said both of her parents have brown eyes, and she also said that her family talks about her eye color by saying the Amharic proverb 'zer keliguam yisbal'. Please look at your friends' physical appearance, such as eye color, hair color, and other physical features. You have probably noticed that different people have different traits. Where do people get these different traits from? Explain your reason. Is there any possibility of having a blue-eyed child from brown-eyed parents? Explain how. Why does a difference appear between parent and offspring?"

*Cooperating* is learning in the context of sharing, responding, and communicating with other students. For example the activities used for sex determination concepts and the case, and the activities were:

> "Henok and his wife, Marta, have six children, all of whom are boys. They both really want to have a daughter, but they cannot understand why they always have boys. Marta thinks that maybe it is her fault that she can only bear sons. The couple decides to divorce and take on a second marriage. Who do you think is responsible for determining the sex of the children (Marta, Henok, or neither)? Explain."

*Transferring* is using knowledge in a new context or novel situation one that has not been covered in class (Crawford, 2001). The activity given for students at transferring phase for heredity and breeding topic was:

> "In human society, religious ethics and modern social norms have consciously judged and forbidden the marriages of brothers with sisters. What do you think of the principles of genetics? (a) Does genetics support or oppose the rules of religion, norms, and cultures of society in relation to this idea? Why? (b) Do you think cross-breeding and selective breeding have disadvantages? How?"

For the second TG, the teacher started the lesson with the introduction of a concept and then presented the context as an exemplar. The context was introduced in the form of a discussion. Afterwards, the teacher makes a transition from contextual discussion to the concept of heredity, and the presentation of context is also continued for further understanding. Gilbert et al. (2011) refer to this as "model 2," which defines context as reciprocity between concepts and applications. In order to assure the implementation of the interchangeable practices between concept and context, the researcher observed the intervention and discussed with the teacher how to reshape the activity.

The basic framework for conventional instruction in the classroom was teacher-centered. The definitions and principles of inheritance were directly presented by the teacher with a brief explanation. The methods were mainly lecturing and questioning; sometimes group discussions were also carried out by students around the questions asked by the teacher. Students were not given real-life contexts to help them see the connection between concepts in real-life contexts. Even the photographs and charts on students' textbooks were not considered for clarity; hence, most students used short notes from their exercise book given by

**Table 1.** Descriptive statistics results of post-SRST

| Groups | n | Mean | Standard deviation | Standard error | 95% confidence interval for mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower bound | Upper bound | | |
| TG 1 | 38 | 15.32 | 5.855 | .950 | 13.39 | 17.24 | 7 | 28 |
| TG 2 | 43 | 21.02 | 5.902 | .900 | 19.21 | 22.84 | 9 | 35 |
| CG | 50 | 14.38 | 4.462 | .631 | 13.11 | 15.65 | 8 | 26 |
| Total | 131 | 16.83 | 6.108 | .534 | 15.78 | 17.89 | 7 | 35 |

**Table 2.** Post-SRST results of groups from analysis of ANOVA

| | Sum of squares | df | Mean square | F | Sig. |
|---|---|---|---|---|---|
| Between groups | 1,143.338 | 2 | 571.669 | 19.739 | .000 |
| Within groups | 3,706.967 | 128 | 28.961 | | |
| Total | 4,850.305 | 130 | | | |

**Table 3.** Post-hoc analysis results of post-SRST

| (I) Group | (J) Group | Mean difference (I-J) | Standard error | Sig. | 95% confidence interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower bound | Upper bound |
| TG 1 | TG 2 | -5.707* | 1.198 | .000 | -8.55 | -2.87 |
| | CG | .936 | 1.158 | .699 | -1.81 | 3.68 |
| TG 2 | CG | 6.643* | 1.119 | .000 | 3.99 | 9.30 |

Note. *The mean difference is significant at 0.05 level

the teacher to answer questions. The teacher generally focused on the questions written in the textbook, which focuses on lower-level learning.

### Method of Data Analysis

In order to determine the effects of the context-based instruction compared with the conventional method of instruction on students' SR skills, the raw data obtained from data sources was analyzed using descriptive and inferential statistics using Statistical Package for Social Sciences (SPSS) version 20 software. These descriptive statistics were examined and tested to ensure that the required assumptions of normality, homogeneity of variance (Levene's test at 5% level of significance), and independence of observations for use with parametric statistical analyses had been met (Morgan et al., 2005). Since the data were fully supported by the assumptions, parametric tests like ANOVA and paired sample t-tests were used. For these reasons, the data obtained from SRST were also categorized, analyzed, and compared among the three groups. The qualitative data were manually transcribed, coded, and categorized into themes for triangulation of information and clarification of quantitative data.

## RESULTS

The results of SRST are presented by counting the number of students who answer the least and most difficult questions, making it possible to consider the mean level of proficiency in each classroom in terms of the level of domain reasoning. Because of the differences in the level of reasoning, the point of an individual can be added by multiplying each item's score by its level of difficulty. Therefore, the scores from different questions and levels can be scaled together after multiplication. The first consideration is whether expected group differences are observed, regardless of instruction. Before the beginning of the intervention, there was no significant difference among groups: $F(2, 128)=.80$, $p=.452$. After completing the implementation of the intervention, data were collected through post-SRST (**Table 1**).

From **Table 1** result, the mean score of TG 1 students was 15.32; TG 2 also scored 21.02; and the mean score of students in CG was 14.38. Therefore, the result showed that students in TG 2 scored better than the other two groups. Students in TG 1 also score better than students in CG. An ANOVA analysis was performed to determine whether the differences were significant. **Table 2** shows the results of ANOVA among groups.

In order to know among which groups the difference was found, post-hoc analysis was conducted. **Table 3** shows the result of post-hoc analysis. TG 2 is significantly different from both TG 1 and CG. But there was no significant difference between TG 1 and CG.

The percentages of students in each group before the intervention were more or less similar at each level of reasoning, and the difficulty level of SR was also observed by decreasing the number of students as the level increased. For example, at level I, the percentages of students in TG 1, TG 2, and CG were 28.95%, 23.26%, and 24.00%, respectively. At level V of SR, this percent decreases to 9.87%, 9.88%, and 10.50%, respectively, for each group (**Table 4**).

**Table 4** indicated that students in all groups showed improvement from pre- to post-tests, and the number of students who answered the question decreased as the level of difficulty of SR increased. Students in TG 2 who learned through an integrated method of teaching, on the other hand, reasoned better than both TG 1 and CG. Students in TG 1 perform better than students in CG. For example, all group members of students perform well at the first and second levels of reasoning: TG 1=68.42%, TG 2=74.41%, and CG=60.00%. But the number of students and percentages differ among groups when the level increases. At level V,

**Table 4.** Pre- & post-SRST results vs. groups

| Group | n | Level I | | Level II | | Level III | | Level IV | | Level V | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pre (%) | Post (%) | Pre (%) | Post (%) | Pre (%) | Post (%) | Pre (%) | Post (%) | Pre (%) | Post (%) |
| TG 1 | 38 | 28.95 | 68.42 | 21.05 | 73.68 | 26.32 | 52.63 | 10.53 | 26.31 | 9.87 | 21.05 |
| TG 2 | 43 | 23.26 | 74.41 | 25.58 | 79.07 | 23.26 | 58.14 | 10.47 | 34.88 | 9.88 | 25.58 |
| CG | 50 | 24.00 | 60.00 | 18.00 | 58.00 | 22.00 | 36.00 | 19.00 | 14.00 | 10.50 | 6.00 |
| Total | 131 | 25.40 | 67.17 | 21.54 | 69.46 | 23.86 | 48.09 | 13.33 | 24.42 | 10.08 | 16.79 |

21.05% of TG 1, 25.58% of TG 2, and 6.00% of CG students answered the process questions. The least number of students answered questions, which need reasoning between generations.

### Qualitative Results

At the beginning of the intervention, the researchers observed that many students in each class were passive in their participation, they were not confident when they reflected their ideas. Only group leaders react to the question raised by the teacher. In the case of TG 1, when the intervention process was going on, they showed a change gradually in their reaction in the classroom to do different activities. Many students were interested, actively participated, and interacted well with their peers to perform the practical activities and discuss the given problem when they were taught about heredity through context based REACT strategy. However, students also commented that:

> "the method is good, but we faced a problem of relating the activity given and the expected learning concepts since the concepts are new to us."

In support of this idea, the researchers observed that call the names of students and objects instead of using the terms in heredity. For example, in cell division activities they did not use the terms centromere, chromatids, and the likes. Students have seen the activities as a game rather than relating the activity with expected concepts. This may increase their interest but may not improve conceptual understanding.

Students who were taught by context-based activities integrated with conventional instruction became confident when they performed different activities. And also, when they reflected on their ideas about the given activities, they used the appropriate terms in genetics instead of using the name of students and objects hence they were introduced at the beginning of the lesson. For example, students in TG 2 call all four nitrogen bases fully by saying Adenine, Cytosine, Guanine, and Thiamine while doing DNA replication activities instead of saying A, G, T, and C like that of students in TG 1.

Students who were taught by conventional instruction had less participation and interest; rather they were passive listeners and their interactions during the discussion were not good. As usual, group leaders speak, and other group members listen to what the leader said.

## DISCUSSION

The pre-SRST descriptive statistics results showed more or less similarity among the three groups. TG 1 had a pre-SRST mean score of 5.11, TG2 had a score of 4.95, and CG had a score of 5.54. The ANOVA analysis of the pre-test results showed no significant difference among groups ($p>.05$, =.452). The post-SRST score ANOVA analysis revealed a significant difference between groups, with TG2 students outperforming both TG1 and CG students ($p=.000$). This could be due to a variety of factors. One possible explanation is that using students' personal daily life experiences as an activity helps them develop their reasoning skills. Likewise, Ultay and Ultay (2014) argued that the activities designed for day-to-day life encourage students to discuss physics for understanding and enhance their reasoning abilities using group talks. Another reason for the improvement in SR skills of students in TG 2 could be group activities that encourage students to ask questions and defend others' ideas based on introduced concepts.

TG 2 students showed significant improvement in their SR skills compared to TG 1 students who experienced REACT strategy. This may be because of the developmental age of students, which means when students perform the activity in REACT strategy, they focus on the game and fail to connect to the targeted concept, and most do not take responsibility for their learning. In order to manage this problem, the teacher should interrupt and guide students' learning by connecting context and concept continuously in the case of integrated methods of instruction. Another reason for the lower level of SR in REACT strategy may be a shortage of time. Because the development of SR might necessarily be a slow and organic process in which the students construct the reasoning for themselves (Adey & Csapo, 2012). Or it could be due to the fact that this is a new concept for them because it was introduced for the first time in this grade level, as well as the nature of the heredity concept, which has been identified as a difficult and complex topic in literature.

The students who were taught using conventional instruction, scored lower than the students in the two TGs. Most students in CG answered the first tier but miss the second tier, which asked a reason for their first choice. This might be because students may gain knowledge but lack understanding of concepts to reason well. Studies also support this finding, as teaching and learning biology content knowledge in the traditional format often do not transfer to help students develop good reasoning abilities (Bao et al., 2018). This implies that the instruction should go beyond conventional instruction if developing students' SR.

The second research question of the study was to investigate the level of SR among TG and CG after intervention. The percentage of students in TG 1 at level I 68.42% and at level V 21.05%, TG 2 students achieved greater as level I 74.41% and at level V 25.58% and CG students 60.00% at level I and 6.00% at level V. These deterioration of percentage of students showed that those questions ask high level reasoning than level I and II reasoning skills. The high percentage of students in TG 2 also showed combined method of teaching facilitates higher order reasoning than REACT strategy and most in advance than conventional method of teaching. Also they might fail to correctly use logical reasoning when making inferences from the known information in answering these questions as suggested by Lawson et al. (2000).

As indicated by Tsui and Treagust (2010), the assessment questions showed the difference in relative difficulties when starting from questions one and two (cause-to-effect), which need low level reasoning, to questions seven through ten (effect-to-cause reasoning), which need high level reasoning. Because of constraints in the Ethiopian curriculum, only monohybrid inheritance was included in this study. But questions requiring an understanding of meiotic events to solve were more difficult than cause-and-effect between-generation problems (i.e., traditional Mendelian inheritance problems), items requiring probabilistic (e.g., 1/1, 12, 14) reasoning. Therefore, students generally provided correct answers for increasingly difficult items only up to the extent of their proficiency and did not miss a lot of easy items while getting difficult items correct.

According to Tsui and Treagust (2010), the bulk of secondary life science instruction does not extend beyond cause-to-effect reasoning, generally in the context of simple inheritance problems using Punnett squares, although simple effect-to-cause problems involving pedigree analysis are sometimes used. And they especially focused on the more complex effect-to-cause problems that require the higher level of reasoning associated with domain expertise. This type of assessment was quite different from Ethiopian assessment mechanisms, as the questions asked for lower-level knowledge that needed regurgitation of facts. The assessment questions developed in this study were novel to the school students sampled. Even if they showed efficiency, students in all groups score much lower than Australian grade ten students, as assessed by Tsui and Treagust (2010). To reason from effects to causes, one generally needs some sort of integrated model of the domain. But our students lack this type of experience. During the interview session, one smart boy told me about the assessment questions, and he gave suggestions for future assessments. He also criticizes exam items prepared by their teacher by relating them to national exam items. He said:

> "Why did you ask this type of question, um, I mean, why are you requesting our reasoning for our response? This makes us confused since it is new. Lower level questions that require recall of biological facts are more common than national exam items. This is because if our teacher asked higher-order questions, only a few pupils would pass the exam, and I think the teacher assumed he had failed in his teaching. As a result, the teacher asked very simple questions to assist all students. If you are concerned about students' reasoning abilities, I recommend beginning in grade seven and continuing through grade ten to help students develop their reasoning skills."

In practical terms, this indicates that students are generally restricted to memorization while learning and assessing. This may be the reason why they score lower than other students, although they are making progress. Hannaway and Hamilton (2008) argued that a shift in the nature of assessment is important if science education is to transform itself from an emphasis on knowledge and the lower-order cognitive demands of recall and comprehension to the higher-order cognitive demands of evaluation and synthesis. Tests that simply demand the lower-order cognitive abilities of recall and comprehension communicate a view about what matters and reinforce a paradigm of pedagogic practice that neither engages students nor meets the contemporary economic requirements for educated STEM professionals. Such a paradigm is deeply embedded in the collective consciousness of science teachers and curriculum developers. This may be the reason why students perform poorly in SR (Osborne, 2013).

During the intervention of this study, the researcher understood and continuously discussed with teachers who teach TG the need of asking continuous questions to dig out the reasoning abilities of students. Students immediately reach the conclusion using their own ideas. For example, when they asked the question of why children are similar to their parents, they immediately responded that it was because of their parents' blood type. They conclude that inheritance occurs through blood simply without considering organisms that have no blood, including plants. In order to catch the idea of inheritance, continuous questioning and using the multiple-hypothesis theory for advanced SR were used, and it was argued that the key to successful reasoning is a reasoner's ability to initiate reasoning with more than one antecedent condition (Lawson et al., 2000). More advanced reasoners also become more reflective and active in seeking alternatives and making inferences when drawing conclusions.

Other students clarified that while a gene is something that is passed down from one's parents, characters are carried from parent to offspring through genes. Students who view a gene as a particle are unable to explain why a feature manifests in a person when neither of their parents possess it. This was seen in the activity, where it was asked why a girl gets blue eyes while both of her parents have brown eyes. Explaining the inheritance of a feature that skips a generation is another challenge for students. This is due to the fact that while genes and DNA molecules are physical, the features they regulate are informational (Duncun & Reiser, 2007).

We consider the contextual aspects of the phenomenon that may lead to the elicitation of those ideas when analyzing the concepts that students bring to bear as they build a mechanistic explanation. Current ideas about knowledge, whether intuitive or acquired through education, imply that it consists of disjointed parts that can be awakened by particular contextual cues and combined into an explanation in particular circumstances (Lynch et al., 2019). When presented in various situations, this knowledge's context-specificity may cause the emergence of various thoughts and explanations for what is basically the same reality. People do not always approach the world with logic. It should not be surprising that these biases manifest themselves in the understanding of genetic causality, as both experts and the general public are susceptible to them when debating cause-and-effect links. Motivated cognition is the most prominent of these in which individuals' ontological ideas about the universe are impacted by their individual and group goals (Lynch et al., 2019). When considering the factors that contribute to human features and behaviors, genes seem to be given special consideration.

Students in TG 1 discussed the sex determination question, and one student said that sex is determined by God using the Amharic term "yihe eko yegiziabiher sira new". The other student tried to negotiate between science and religion by saying, "sex is determined by sperm cells, which contain sperm chromosomes, but the chance of getting male or female is determined by God." Another student also asked, "Do you think you can get a child without sexual intercourse?" And students respond that it cannot be. At last, they reach consensus on the idea that Henok is responsible for their children's sex determination, and this is not the fault of Marta. As a result, culture, religion, and other values influence how we reason about and comprehend natural phenomena.

The students in this study can use the punnet square to solve the monohybrid inheritance problem, but they are unable to connect the meiotic process with the generation of gametes; instead, they just separate the two alleles. When asked why they only used one allele or letter to cross, they were unable to explain. As a result, process thinking was a problem for the majority of students. In the case of question number five, which asked level IV reasoning, students who correctly chose the answer had a good understanding of the dominant-recessive pattern because first they were expected to know the first husband's blood type, either homozygous or heterozygous, to give a blood type O child. In order to have a blood type A child, the nest father must be blood type B (homozygous or heterozygous). They could also identify the individual in the second generation as having two recessive alleles in his genotype and being blood type O, coming from heterozygous parents for the trait. It must be noted that only two heterozygous parents or carriers in the second generation can give rise to one homozygous recessive son. Students who failed to correctly answer this item might not have fully understood the meaning of the terms in genetics and their underlying concepts; therefore, they were unable to reason well (Tsui & Treagust, 2010).

The question that was asked about the chromosome number of the nerve cell needs the idea of meiosis (Level V reasoning), the reduction of cell division for producing haploid sperm or eggs. As this item is used by students, those with a good understanding of the process of meiosis and its relation to body cells should be able to correctly answer this item. However, those who memorized the number of chromosomes in a human cell automatically chose choice D, which contains 23 pairs of chromosomes, without understanding the concepts and their relations.

## CONCLUSIONS

In conclusion, the present study assured that a context-based approach integrated with conventional methods of teaching was found to be useful in order to enhance students' SR skills. Supporting the context-based approach with conventional methods of instruction is significantly better than both REACT and conventional methods of teaching alone. The activities designed based on the syllables of Ethiopia in order to facilitate students' reasoning by focusing on "how and why" questions instead of asking low-level questions are recommended. This study was limited to one chapter on the topic of heredity for six weeks. It is recommended that semester- or annual-level intervention be needed to extend the effect of a context-based approach on SR skills of students.

### Implication

Students need to be exposed to reasoning skills in the classroom or teaching style in order to generate students with reasoning abilities and higher-level thinking. As a result of the talks to make students more focused and the reflection on making skills relevant to current issues in their everyday lives, the strategy of a context-based approach is very well suited to the biology topic. Discussion of context-based activities needs to be emphasized so that students are not only able to find solutions to problems and make decisions, but also so that they can practice them in their daily lives. It is hoped that these context-based activities might be included in biology curricula.

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