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Addressing Misconceptions in Biology Using Design Thinking as A Framework

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ABSTRACT

Despite the importance of science in our everyday life, a decline in students' academic performances and interest towards Biology have been empirically publicized by several researchers. Though multifactorial, misconception remains one of the key factors affecting students' understanding of concepts, exam grades and interest. Consequently, the literature is gauged with empirical research focusing on the appropriateness of different methods and strategies used to identify and clear students' misconceptions in Biology. This case study uses a mixed epistemological stance to study the appropriateness of using the DTSICM (Design Thinking Strategy to Identify and Clear Misconceptions) model, underpinned by the Stanford's design thinking framework, in identifying and clearing the misconception of twelve low-performing students in Biology. The findings revealed that (i) the use of design thinking-based DTSICM approach is efficient in clearing students' misconceptions, with statistical significance at 5% level ($p>0.05$), and (ii) the design thinking approach provide teachers with a formalised, context-driven, needs-based and adaptable pathway to identify and clear misconceptions of students, by engaging through the five decisive stages of the design thinking framework, namely 'emphasize', 'define', 'ideate', 'prototype' and test'.

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INTRODUCTION

Learners' misconceptions remain very common in biology, firstly because many daily life events and experiences are related to biological concepts (Prayitno & Hidayati, 2022; Nguyen and Rosengren, 2004); secondly because scientific concepts are often abstract mental representations of the world and its natural phenomena (Yates and Marek, 2014); and thirdly because some concepts in biology remain complex, elusive and even hidden or not completely elucidated

(Rouvray, 1992, Ogundare et al., 2024). A review of the literature revealed that misconceptions commonly occur in mostly all topics taught in biology at secondary school level such as animal nutrition, transport, breathing, gas exchange, respiration, inheritance, and photosynthesis amongst others. However, this case study focuses on photosynthesis, which is a topic that has been closely associated with misconceptions in the literature (Atchia et al., 2024). For instance, Venter (2023) stated that learners are often confused between photosynthesis and respiration, and, Karakaya at al. (2021) highlighted that learners hold misconceptions about the definition of photosynthesis, its role as an energy source and even on its importance for the ecosystem.

Moreover, Atchia et al. (2024; 2022) showed that misconceptions in photosynthesis are highly prevalent amongst the Mauritian students. One of the main reasons of the high prevalence is that teachers often oversimplified the process of photosynthesis to fit students' level of comprehension, as the topic is introduced at a very early stage of their primary schooling. Another reason is that concepts related to photosynthesis are closely associated with preconceived notions (misconceptions), as it forms parts of students' daily life experiences. In fact, Brenner (2020) explained the link between the concepts of photosynthesis and our daily experiences through facts such as: (i) producers release the oxygen supporting life on planet Earth, (ii) photosynthesis is directly or indirectly responsible for the fulfillment of our requirements for food as producers represent the first trophic level in food chains and food webs, and (iii) all energy found in wood, petroleum products or gas indirectly comes from the sun via the photosynthetic pathway.

Considering the impacts that misconceptions have on students' understanding of biological concepts and thus on exam grades, the literature is gauged with a variety of different strategies, methods, frameworks and models that have been used to identify and clear misconceptions. One of the strategies is the DTSICM (Design Thinking Strategy to Identify and Clear Misconceptions) model, developed and tested by Atchia (2022; 2024). Motivated by preliminary studies and the motivation to understand the pertinence and transferability of the model in different educational settings, this study investigate its use within a previously unexplored educational setting, which predominantly serves low-achieving students. .This case study is underpinned by the 'Stanford model of design thinking', as depicted in Figure 1.

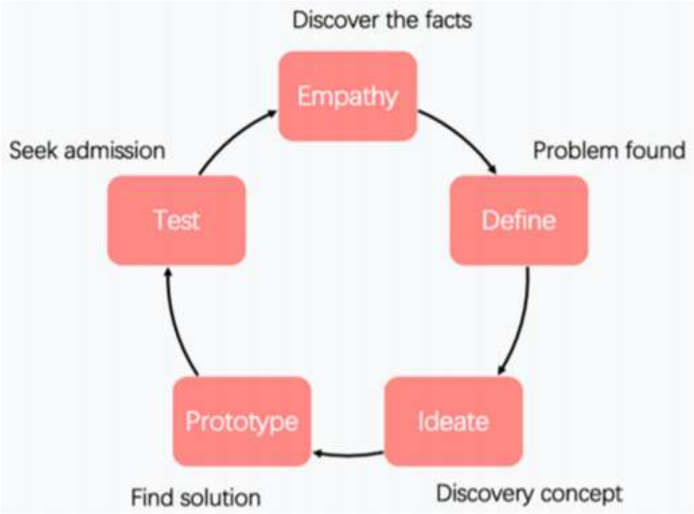

Figure 1. The Stanford Model of Design thinking (Haso-plattner, 2011)

The model is based on the concept of design thinking, which was once a term used solely to describe how designers process information. Yet, it evolved into a multidisciplinary concept (Tschimmel, 2012) relevant to all disciplines and professions (Lindberg, Noweski & Meinel, 2010) and is increasingly finding its way in the field of education (Author, 2021; Henriksen et al., 2017). Design thinking is essentially a process used to find innovative and creative solutions to different problems in a way that is tailored to the users' needs. According to Dam and Siang (2018), this is made possible by the efforts dedicated towards understanding the user and the problem, in addition to considering the possible consequences of any attempt to solve the problem. It has been argued that the iterative approach of this process makes it suitable to tackle emerging challenges for which there are no prescribed solutions and to avoid the pitfalls of ill-suited design. These types of problems are encountered on a daily basis in educational practice at all levels including teaching and learning. Bullough (2012) argues that the uniqueness and complexity of teaching and learning issues cannot be resolved through linear thinking and requires a creative approach like design thinking. The DTSICM model provides a complementary approach to well-established frameworks for clearing misconceptions, such as the Conceptual Change Model.

RESEARCH METHODS

This section describes the sample, research design and data analysis used in this study.

Sample

The sample comprised twelve grade 9 slow learners, including four boys and eight girls, from a public secondary school found on the South-East coast of the island of Mauritius. The school houses about 200 students and is the only mixed regional state secondary school in the country. Most students attending the school are low-performing students from families with low socio-economic backgrounds. Analysis of their academic performances revealed a declining trend from 37.5% in 2017 to 21.4% in 2021 at O level. In fact, the school recorded a pass rate of 18.2% compared to 70% national pass rate in the 2021 National Certificate Exams (NCE), which marked the end of the first cycle of the 'nine years continuous basic schooling' (Mauritius Examination Syndicate, 2021).

Research design

The DTSICM model, as depicted in Figure 2, was used as the research design guiding the case study.

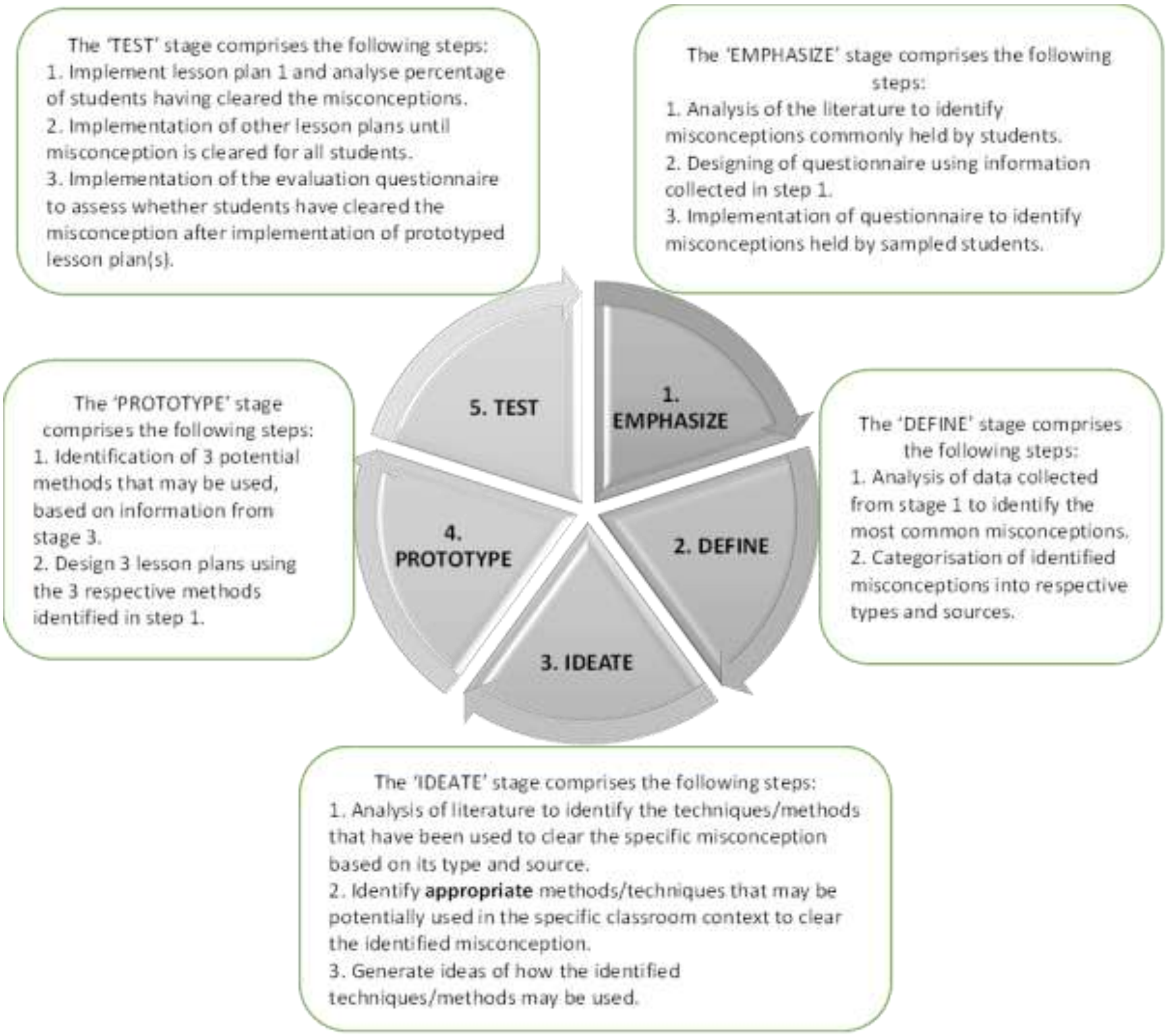

Figure 2. The DTSICM model (Author, 2022)

The DTSICM model comprised the following 5 stages.

Stage 1: Empathise

This is an empathic stage where the teacher analysed the literature to identify misconceptions that are commonly held by students on photosynthesis at lower secondary school level. The identified misconceptions were then used to prepare a two-tier MC (Multiple Choice) diagnostic questionnaire to be administered with the sampled students to (i) verify whether they hold the same misconceptions, (ii) identify the most prevalent misconception, and (iii) explore the type and origins of the misconceptions. In fact, the diagnostic questionnaire comprised two-tier questions, where the main question identifies whether the student holds the misconception and the second question captures the reasons behind their choice of answers (Kautz and Timmermann, 2015).

Stage 2: Define

This stage involved the analysis of data derived from stage 1 to define the problem in a more precise way. In fact, this stage moved beyond the mere identification of the most prevalent misconceptions held by learners to define the origin and types of the misconceptions. These information are key to guide teachers selecting the appropriate context-driven methods to be used for clearing the misconception.

Stage 3: Ideate

This stage involved the generation of ideas to solve the problems identified in the previous stage. During the ideate stage, several methods to clear misconceptions are identified from the literature taking into consideration the origin and type of the misconception to be cleared and the abilities, competencies, and needs of the sampled students. This is followed by a brainstorming session involving experienced biology teachers of the same department to discuss the efficiency of the methods selected to clear the identified misconception.

Stage 4: Prototype

Based on the discussion during the ideate stage, the three methods selected to clear the identified misconception were used to produce three prototyped lesson plans. In this study, the three methods selected to clear the most prevalent misconception on photosynthesis were 'guided Inquiry-Based Learning (IBL)',' video-based learning', and 'traditional lecturing'. The latter was used as a control to compare the efficiency of the two other methods in clearing the misconception.

Stage 5: Test

Four participants were randomly assigned to each of the three treatment groups and the three lesson plans designed in the prototype stage using traditional lecturing, guided inquiry-based learning and video-based learning were implemented. After the implementation phase, selected questions were used again to find out whether students' misconceptions have been cleared.

Data analysis

Using the explanatory sequential mixed design methodology, both quantitative and qualitative data were generated. Considering the quantitative analysis, the data collected at different stages of DTSICM model were statistically analysed using Rstudio, whereas the appropriateness of each teaching method used to clear the identified misconception were tested using McNemar's chi-squared test at critical p-value of 0.05. As far as the qualitative data is concerned, the data collected through observation by researcher and co-researcher during the implementation of the DTSICM model, and the data generated from focus group discussions were recoded, transcribed, and analysed by the research group to identify relevant statementsThis providing a more complete and nuanced understanding of the investigation than either approach could offer alone.

RESEARCH RESULT

This section presents the findings in the order of the stages depicted in the DTSICM model shown in figure 2, as follows:

Stages 1 and 2: Empathise and Define

Table 1 shows the misconceptions held by the sampled students on photosynthesis (pitched at lower secondary content level) and the percentage prevalence of each misconception, which was calculated as follows:

$$\text{Percentage prevalence (\%)} = \frac{\text{number of students holding the specific misconception}}{\text{total number of students}} \times 100\%$$

Table 1: Percentage prevalence of misconceptions held by sampled students on photosynthesis

No.	Common misconceptions held by sampled students on photosynthesis.	Percentage prevalence (%)
1.	Sunlight is the food of plants (Keles & Kefeli, 2010).	66.7
2.	The food of a plant is water and minerals from the soil (Keles & Kefeli, 2010).	50.0
3.	CO_2 is food for plants (Keles & Kefeli, 2010).	91.7
4.	Photosynthesis is the respiration of plants (Keles & Kefeli, 2010).	50.0
5.	Sunlight is converted into food in photosynthesis (Keles & Kefeli, 2010).	75.0

No.	Common misconceptions held by sampled students on photosynthesis.	Percentage prevalence (%)
6.	Carbon dioxide is converted into oxygen in photosynthesis (Keles & Kefeli, 2010).	83.3
7.	Plants do not use oxygen (Keles & Kefeli, 2010).	66.7
8.	Carbon dioxide and chlorophyll are produced at the end of photosynthesis (Ekici et al., 2007).	66.7
9.	Only green plants make photosynthesis (Ekici et al., 2007).	66.7
10.	Plants grow up by photosynthesis, which occurs during the day (Köse, 2008).	83.3
11.	Photosynthesis and respiration in plants are only a gas exchange event (Köse, 2008).	66.7
12.	The most important benefit to green plants when they photosynthesize is giving off oxygen (Köse, 2008).	83.3
13.	Chloroplast and chlorophyll are the same thing (Halim et al., 2018).	41.7
14.	Water moves into the leaves during photosynthesis (Köse, 2008).	66.7
15.	Chlorophyll is only found in the leaves. Therefore, photosynthesis only takes place in the leaves (Marmaroti & Galanopoulou, 2006).	66.7
16.	Photosynthesis only takes place during the day (Marmaroti & Galanopoulou, 2006).	66.7
17.	The form of energy provided by the sun is light and heat energy OR only heat energy (Marmaroti & Galanopoulou, 2006).	50.0
18.	Energy is produced during photosynthesis (inability to recognise energy conversion) (Marmaroti & Galanopoulou, 2006).	50.0
19.	Oxygen is a raw material for photosynthesis (Marmaroti & Galanopoulou, 2006).	66.7
20.	Chlorophyll is either a product or a reactant in photosynthesis (Marmaroti & Galanopoulou, 2006).	75.0

Table 1 shows that misconceptions 3 (91.7%), followed by 6, 10 and 12 with 83.3% are the most prevalent misconceptions held by the sampled students. Analysis of scripts revealed that most students were confused about the raw materials and end products of photosynthesis. Of particular concern, most students of the sample misidentified carbon dioxide as an end-product of photosynthesis instead of the substrate (raw material). It is hypothesized that the misattribution of carbon dioxide as a product rather than as a substrate is related to the fact that carbon dioxide is the final product of familiar processes such as respiration and combustion. Since a false equivalence is being applied in the case of photosynthesis, misconception 3 was classified as a conceptual misunderstanding (Patil, Chavan and Khandagale, 2019), originated from students' past experiences and past exposure to oversimplified knowledge on photosynthesis.

Stage 3: Ideate

During the brainstorming session with experienced teachers of the biology department, the data gathered in stages 1 and 2 on prevalence, types and origins of misconceptions were presented to situate the context of the discussion around the identification of potential methods that may contextually be used to clear the identified misconceptions. The abilities, academic performance, competencies and needs of students were taken into consideration to validate the three methods to be used for clearing the most prevalent misconception.

The first method identified is the traditional 'lecture or expository' method. This method was chosen since it remains the most prominent form of study in most Mauritian schools. In addition, it is suitable as a control group since it is the default mode of study (Balcı, 2005). The second method identified is the 'guided inquiry learning', which offers a sharp contrast to the traditional method as it involves the active participation of the students in the learning process. It is based on creating a conflict in students' mind to eventually engage the students in discovering and constructing the correct conception of photosynthesis. This method, based on the constructivist approach, has been efficiently used to clear conceptual misunderstandings (Author, 2022). The third method identified is the video-based learning (VBL), which is a flexible method whose effectiveness is largely dependent on the way it is used. If wrongly applied, it mirrors the traditional teaching method albeit with a visual interface. When properly applied, VBL can be a student-centered method (Giannakos, 2013).

Stage 4: Prototype

Based on the previous stage, three prototyped lesson plans as depicted in table 2 to 4 were designed and validated by colleagues' biology teachers before implementation at classroom level to clear the most prevalent misconception.

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Table 2: Prototype 1 (Lesson plan using the traditional expository method)

Lesson Plan 1			
Class:	Grade 9	**Topic:**	Raw materials and end products of photosynthesis
Number of students:	4		
Time:	1 hour	**Teaching method:**	Traditional teaching and learning
Teaching aids and resources:	1) Science Textbook Grade 9 (MoEHRTSR) 2) Laptop and projector with slides on photosynthesis (mostly text and pictures)		
Procedure: 1) Students polled on the need for nutrition and asked how plants obtain food 2) Introduction of the term "photosynthesis" 3) Diagram of plant used to explain how: -carbon dioxide diffuses from the atmosphere into the leaves -water is absorbed from the soil by the roots 4) Explanation of synthesis of glucose as the food product and oxygen as a by-product 5) Identification of light as a source of energy and chlorophyll as the agent trapping sunlight 6) Classifying carbon dioxide and water as raw materials and glucose and oxygen as end products 7) Review and summary of lesson 8) Students given questionnaire paper to test for conceptual change			

Table 3: Prototype II (Lesson plan using GIL method)

Lesson Plan 2			
Class:	Grade 9	**Topic:**	Raw materials and end products of photosynthesis
Number of students:	4		
Time:	2 hours (excluding overnight wait time)	**Teaching method:**	Guided Inquiry Learning
Teaching aids and resources:	General laboratory equipment, Elodea plant, bromothymol blue, sodium carbonate		
Procedure: 1) Students investigate colour change when carbon dioxide is blown into solution containing bromothymol blue 2) Students investigate further colour changes when Elodea plant is left in same solution overnight 3) In another experiment, students investigate gas given off when Elodea plant is left in solution containing sodium carbonate 4) Gas is collected by using inverted funnel with test tube on top. Elodea plant is kept under funnel overnight 5) Students perform test for gas 6) Discussion with students regarding results of both experiments 7) Identification of raw materials, end products and conditions for photosynthesis 8) Students given questionnaire (Appendix 4) to assess conceptual change			

Table 4: Prototype III (Lesson plan using VBL method)

<table>
<tr><td colspan="4">Lesson Plan 3</td></tr>
<tr><td>Class:</td><td>Grade 9</td><td rowspan="2">Topic:</td><td rowspan="2">Raw materials and end products of photosynthesis</td></tr>
<tr><td>Number of students:</td><td>4</td></tr>
<tr><td>Time:</td><td>1 hour</td><td>Teaching method:</td><td>Video-based learning</td></tr>
<tr><td>Teaching aids and resources:</td><td colspan="3">Videos:
• Photosynthesis and elodea by Tawnia Vanserwood (https://www.youtube.com/watch?v=SZsQG_rPJwQ)
• “Photosynthesis” experiment (How to make oxygen at home) (https://www.youtube.com/watch?v=Uiuct-2yAxA&t=10s)</td></tr>
<tr><td colspan="4">Procedure:
1) Students view 1st video
2) At key points, teachers stop video, probe students’ understanding and invite discussion
3) Students view 2nd video
4) Same as step 2
5) Identification of raw materials, products and conditions for photosynthesis
6) Students given questionnaire (Appendix 4) to assess conceptual change</td></tr>
</table>

Stage 5: Test

This stage involved the implementation of the prototypes as attempts to clear the most prevalent misconception. Though three prototypes were planned, all the sampled students cleared the misconception after implementation of prototype II. The engagement of students during implementation of prototype II, as evidenced in figure 3, allowed them to construct the correct knowledge on the process of photosynthesis and simultaneously clear misconception 3.

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a. Student start blowing into bromothymol blue solution.

b. The bromothymol blue solution changes colour due to the acidic CO_2 found in exhaled air.

c. Elodea plants placed in beaker containing bromothymol blue solution.

d. Solution turns blue when beaker was left in the sun for fifteen minutes, indicating that CO_2 is used up by the elodea plants

e. Setting up of apparatus by students

f. Formation (bubbles) and collection of O_2 gas (product of photosynthesis).

Figure 3. Pictures evidencing students' engagement during implementation of prototype II

Efficiency of the methods in clearing students' misconceptions

This section presents the findings of the quantitative and qualitative data analysis used to depict the efficiency of the methods used to clear the most prevalent misconception identified amongst the sampled students. As long as the quantitative analysis is concerned, a post-test was given after implementation of each prototype to find the new percentage prevalence of the misconception amongst the sampled students. Figure 4 shows the number of students holding the most prevalent misconception before and after implementation of the prototypes.

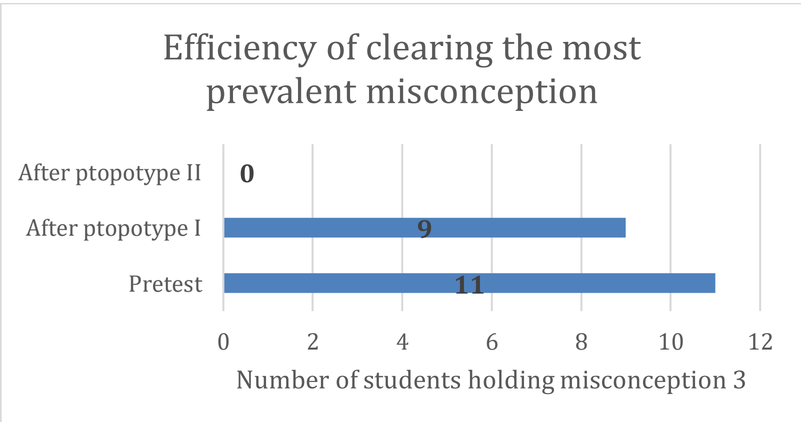

Figure 4: Testing of prototypes in clearing misconception 3

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Figure 4 shows that the implementation of prototype I (traditional expository method) reduced the number of students holding the misconception from 11 to 9 representing a drop in percentage prevalence by 16,7%. Implementation of prototype II cleared misconceptions of the remaining students, showing a net decrease of 75%. As the misconception was cleared for all students after implementation of prototype II, prototype III was not implemented. Moreover, the results of McNemar's chi-squared test for independence between individual learning strategy and conceptual change showed that there is statistical significance at 5% level for guided inquiry learning ($p=0.046, p<0.05$) but not for the traditional expository method ($p=0.157, p>0.05$) in clearing misconception 3. As long as the qualitative analysis is concerned, participants' transcripts were screened to select the relevant statements as presented in table 5.

Table 5: Selected statements of participants on the efficiency of DTSICM model to identify and clear misconception

Participants	Feedback and comments
Sampled students	"I am used to simple multiple-choice (MC) questions rather than the double (two-tier) MC questions. I feel that it is interesting as it gave me the opportunity to reflect on and justify my choice of answer instead of randomly selecting one." "Though the teacher explains well (expository method), I prefer learning through practical work (Guided Inquiry method)" "I felt really motivated when engaged in the practical work." "In the first method (expository), expectation of the factor was limited to students correctly reproducing the equation of photosynthesis and correctly identify the substrates and products, whereas in the second method (inquiry), I discovered the process by inferring from my observations, data collection and analysis. I can say that this allowed me to understand the process of photosynthesis without the need to learn by heart". "Maybe next time we could try changing the plant or adding some animals in the tube." "I would like to retry the experiment again because it was very interesting." "I scored badly in the first test, but I am happy that I made it correctly for the last test." "The whole process was much more interesting compared to our usual class. We were fully motivated. I like this type of class."
Teacher	"The DTSICM model is very useful as it provides a structured pathway allowing teachers to identify and clear misconceptions." "The model has a pro-active approach where teachers are first confronted with common misconceptions during analysis of literature to eventually prepare the diagnostic tool and prototypes. This allowed teachers to not only prepare lessons to develop knowledge but also to clear students' misconceptions. Moreover, lessons delivery become more contextualised."

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Participants	Feedback and comments
	"I was not even aware that I also hold misconceptions on photosynthesis and could have been a vector of the misconceptions. This model allows teachers to reflect on our role in relation to misconceptions." "By using this model, I realised that teacher-centered approach cannot clear misconceptions of all students. A paradigm shift towards student-centered approach is important, in which the teachers remain the key agent of change." "Though it requires more preparation, I was motivated throughout and most importantly convinced. "I realised that teaching and learning cannot be efficient without focusing on students' needs and clearing of their misconceptions." "Though time can be a major constraint, I feel that if well organised it is doable." "I really advise other teachers to try the model as it makes teaching and learning more meaningful. As far as I am concerned, a try has turned into adoption." "Some of the methods I have previously been using to clear misconceptions were not appropriate. Some students still hold the misconceptions I wanted to clear up. However, the DTSICM model allows teachers to select appropriate methods based on types and origin of misconceptions. It is genuinely a well-thought model." "The methods used to clear misconceptions should cater for all students and not only for few as no one should be left behind. This is provided through the different prototypes." "Design Thinking offers a very flexible approach to conceptual change." "The process triggered the students' creative and inquisitive sides"

These findings indicate that both students and the teacher unanimously support the use of the DTSICM model to identify and clear misconceptions.

DISCUSSION

Analysis of the quantitative and qualitative data generated in this case study supports the use of DTSICM model to identify and clear students' misconceptions in biology. It also showed that it works well to clear misconceptions of low performing students. The voices of the participants pertinently expound that the different stages not only provide a coherent, structured, and contextualised pathway to engage teachers and students in the identification and clearing of misconceptions, but also provides opportunity for teachers to reflect on their practice and their own misconceptions. As compared to other conceptual change models commonly evidenced in the literature, the DTSICM model (i) is not a one size fits all model as it adapts to specific context and students' needs, (ii) allows identification of both students' and teachers' misconceptions, (iii) is grounded in the literature, as it includes a preliminary analysis of literature to identify common misconceptions and a secondary analysis to select methods for clearing the identified misconceptions, (iv) allows selection of appropriate methods based on types, and origin of misconceptions, (v) provides opportunities to clear misconceptions of **all** students,(vi) is based on the concept of differential pedagogy, using prototypes based on different approaches, and (vi) is based on the use of the constructivist approach of design thinking which engage both students and teachers in the process of learning.

As far as the efficiency of the model to identify students' misconceptions in science and particularly biology is concerned, implementation of the diagnostic questionnaire where students are confronted with all misconceptions commonly held by students, allowed to take onboard all common misconceptions identified in the literature. In fact, this case study showed that all the misconceptions identified from the literature were also present to different degrees in the sampled participants, which corroborate with the findings of other researchers such as Marmaroti & Galanopoulou, (2006), Ekici et al. (2007), Köse (2008), Keles & Kefeli (2010), and Halim et al. (2018). Moreover, the use of the two-tier multiple-choice questionnaire was revealing in the sense that it gave further indication to what degree photosynthesis is misunderstood in addition to the types and origins of the misconceptions. It also showed that the percentage of students with correct concepts drops when asked to provide justification for their answer. This implies that the few students who answered the main question correctly did so at random. The use of two-tier multiple-choice questionnaires is therefore highly recommended for more accurate diagnosis of misconceptions.

The findings seem to indicate that guided inquiry learning is a better strategy for clearing misconceptions compared to traditional learning. Hussain, Azeem & Shakoor (2011) found significant effect of guided inquiry learning in conceptual understanding and application of physical concepts compared to the traditional method. Our results demonstrate a similar effect in conceptual change regarding the topic of photosynthesis. It is possible that the active participation of learners in the inquiry lead to better understanding of scientific concepts. It might also be easier for learners to come to terms with their cognitive dissonance when they directly observe the results of an experiment that they carried out themselves as opposed to simply being told by their teachers that they hold misconceptions.

The DTSICM model can be a powerful tool for diagnosing and addressing misconceptions. The division of the process into different stages allows any issues that may come up during any of its stages to be identified, accurately situated, and immediately corrected. This increases the efficiency of the process by saving time that could otherwise be wasted in searching for a problem across the whole process. Moreover, the model allows for more flexibility as the user is given the opportunity to creatively plan several possible solutions to a problem and to select the most appropriate methods. In this study, we were able to choose the methods with which we diagnosed the misconceptions and the strategies to clear them, both of which can be altered to suit different learner profiles, educational contexts, and resource availability.

Limitations Of The Study

While this study offers important and contextualised insights, several limitations must be acknowledged. The primary limitation is the small sample size (N=12). However, to contextualise this constraint, it should be noted that the sample constituted the entire population of science students at this grade level within the participating school. This is a common characteristic of research conducted in low-performing schools, which often have smaller student population. Consequently, while the findings provide a rich, in-depth understanding of this specific context, their generalisability to larger, more diverse school populations is limited. Future research should seek to validate these results across multiple schools and larger cohorts.

A second limitation concerns the implementation of the designed prototypes. Although Prototype III was fully developed, it was not deployed in the classroom. This decision was made pragmatically upon finding that the application of Prototype II had already successfully addressed the target misconceptions, thereby obviating the need for a subsequent intervention. Finally, the study lacked longitudinal follow-up, meaning the long-term retention of the conceptual change observed remains an open question for future investigation, which opens to further research in such educational settings.

CONCLUSION

The DTSICM model is an agile and iterative model centered around user needs or demands and context. It provides a structured, contextualized, adaptable, and coherent pathway allowing teachers to successfully identify and clear students' misconceptions. Based on its constructivist design thinking approach, it provides teachers and students a conducive student-centered environment where knowledge, skills, attitudes, and values are developed. And based on its reflective nature, it provides teachers with opportunities to reflect on their own misconceptions and their teaching and learning practices. In fact, the DTSICM model provides a structured pathway to (i) identify students' misconceptions by using a literature-grounded diagnostic evaluation, (ii) ensure teachers understand the types and origins of students' misconceptions, (iii) select the most appropriate and context-driven methods to clear misconceptions and (iv) ensure that all students are taken onboard. The iterative nature of the design offers possibilities to test effectiveness, redefinition of the problem and trial of other prototypes.

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