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Innovation of Constructivist Teaching Sequences Model Based on Technology in Biology Material

Asyah Dwi Hastika*, Lidya Betty Setiyaningsih, Yenni Verawati, Bambang Supriatno, Riandi
Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
asyahdwi44@upi.edu*; lidyabettysetiyaningsih@upi.edu; yennivsagala@upi.edu
*Corresponding author

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ABSTRACT

The learning model is a logical stage for learning students. The learning process must pay attention to the steps that become the basic framework for creating an effective and meaningful student learning process. This study aims to innovate biology learning in metabolism material. The innovation is done by integrating several technologies namely Wordwall, Virtual Lab, and Ms. PowerPoint on the Constructivist Teaching Sequence model. The research method used is a literature review sourced from books, journal articles, research reports, and other relevant documents. This research flow has several stages consisting of literature identification, literature selection, literature analysis, synthesis of findings, and learning model innovation design. The result of this research is an innovative learning recommendation using the technology-assisted Constructivist Teaching Sequence model that can be an alternative high school biology learning model.

Introduction

Learning in the educational process plays an important role in achieving the goals of national education in Indonesia. Biology is a science that discusses living things and nature and the processes that exist in it (Hastika & Supriatno, 2023). According to Widodo (2021), There are two major goals that teachers want to achieve in the process of learning science, including biology. The first goal is the scientific knowledge aspect while the second goal is a combination of scientific knowledge, scientific process and scientific attitude aspects. Each goal has different characteristics that require different learning models.

Education considers lifelong learning processes. Learning means making meaning from real-life practices and experiences (Mohammed *et al*., 2020). Learning builds on students' prior knowledge. Constructivist teaching approaches, rooted in the theories of Piaget and Vygotsky, emphasize that knowledge is actively constructed by learners through interactions with their environment rather than passively received. This paradigm encourages students to build on prior knowledge, engage in problem-solving, and develop a deeper understanding of complex subjects. In science education, especially biology, these strategies are

particularly relevant due to the abstract and intricate nature of topics like cellular processes, genetics, and ecological systems.

All learning models are basically designed to help students achieve their goals. Learning models actually talk about the stages of thinking that occur in students' brains, not the stages of teaching. A learning model has stages that result in a learning process by students so that learning becomes meaningful and achieves learning objectives. Learning models can be developed by referring to the learning theory adopted by the model developer. One of the learning models based on the learning theory of constructivism is Constructivist Teaching Sequences (Widodo, 2004) which consists of 5 stages, namely introduction, exploration, restructuring, application and review.

Teachers cannot simply transmit knowledge to students, but it is students who need to actively build knowledge in their own minds. This kind of learning process is present in the constructivist view of learning. The growth of competencies in learning will be created if the learner as an active agent in the knowledge acquisition process. Constructivism learning model is a learning model that is oriented towards student centered learning, which views students as active individuals and can build their own knowledge (Leach & Scott, 2002; Toraman & Demir, 2016). The Department of National Education (2003) also specifically mentions that science learning in schools should consider the principles of constructivism. This is in accordance with learning described as an experience. Students should be taught how to learn. Teachers should make the subject matter directly relevant and meaningful to students. Constructivist teaching, in contrast, encourages students to engage in discovery and collaborative learning, thereby promoting a more student-centered and inquiry-driven learning environment (Taber, 2014).

The integration of technology in biology education has revolutionized the way students learn and engage with biological concepts. However, with the rapid advancement of information and communication technology (ICT), there is a growing need to integrate technology into biology learning to make it more engaging, relevant, and effective (Cartono, 2023). This integration not only increases student engagement but also fosters a deeper understanding of theoretical concepts through practical applications (Firdaus *et al*., 2022). Recent studies highlight the growing role of technology in supporting constructivist approaches by creating interactive, dynamic learning environments. Tools such as simulations, virtual labs, and digital models allow students to experiment with biological processes in ways that were previously not possible in conventional classrooms (Rosen & Salomon, 2007; (Noroozi *et al*., 2021).

Research has shown that when students engage with technology-based learning environments, they are more likely to demonstrate improved conceptual understanding and higher-order thinking skills (Koehler *et al*., 2013; Noroozi *et al*., 2024). These tools also cater to diverse learning styles, offering multiple pathways for students to explore and interact with biology content (Rutten *et al*., 2012). In this study, we aim to develop a Constructivist Teaching Sequences Model (CTSM) based on technology for biology materials. While constructivist approaches have been previously explored, the unique aspect of this study lies in its emphasis on utilizing advanced technological tools—such as simulations, interactive videos, and collaborative platforms—to foster active learning and deeper conceptual understanding. This approach not only enhances student engagement but also facilitates personalized learning experiences tailored to individual needs. The proposed model is designed to integrate multimedia, simulations, and collaborative tools to provide students with hands-on, inquiry-based learning opportunities.

Method

This research method uses literature review through data collection from various references such as books and scientific articles. According to Creswell, (2012), Literature review is the process of collecting existing literature including sources such as books, journal articles, research reports, and other relevant documents to provide basic information and theory for the research being conducted. In this study, studies were conducted related to the constructivism-based learning model, namely the Constructivist Teaching Sequence (CTS), and learning media technology used such as word wall, virtual lab application, and Microsoft PowerPoint application in high school learning. The flow of this research consists of several stages which can be seen in Figure 1 below.

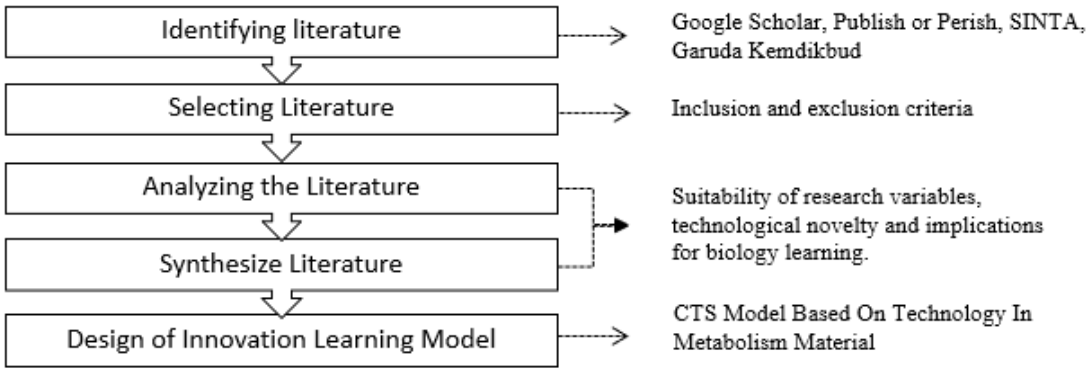

Figure 1. Research Flow

Results and Discussion

Constructivist Teaching Sequence as a Learning Model Based on the Theory of Constructivism

All learning models are basically designed to assist students in achieving goals. Learning models can be developed by referring to the learning theory adopted by the model developer. According to (Widodo, 2007), there are several views of constructivism towards the learning and teaching process, namely: 1) Students as learners already have prior knowledge, meaning that there is no learner whose brain is completely empty. The learners' prior knowledge plays an important role during the learning process which will be associated with what they already know; 2) Learning is a process of forming knowledge from pre-existing knowledge, meaning that knowledge cannot be transferred directly but the learner himself constructs it; 3) Learning results are in the form of changes in conception, meaning that students' initial knowledge develops or changes according to the concept; 4) Social plays an important role in the knowledge construction process; 5) The learner is responsible for his learning process, meaning that the teacher is only a facilitator in preparing conditions that allow students to learn, the actual learning process depends on the students themselves.

The Constructivist Teaching Sequence learning model is a learning model based on constructivism learning theory which views that knowledge is not transferred directly from teacher to student, but students carry out the process of forming their own knowledge. This learning model is considered suitable for learning biology, especially on complex metabolic material. Through a constructivism-based learning model, it encourages students to conduct inquiry activities and perform science process skills needed in learning biology, such as observing, classifying, interpreting and so on. The Constructivist Teaching Sequence was

developed by Driver in 1989 in the Children Learning in Science Project in the UK. This learning model has several characteristics or hallmarks such as, student-centered learning through hands-on and minds-on activities towards learning resources, the development of student ideas or ideas sourced from observations or experiments, as well as learning to pay attention to students' experiences and initial conceptions. Based on research Amineh & Asl (2015), Constructivist Teaching Sequence learning model also has several advantages including: (1) Providing opportunities for students to be more active in the learning process, (2) Learning is more meaningful because it provides experiences related to ideas that students already have, (3) Creating science process skills through contextual activities, experiments and simulations, (4) Making it easier for teachers to teach by creating a more active learning atmosphere.

Technology Integration in Constructivist Teaching Sequence Learning Model on Metabolism Material

Today, the development of the global world requires education to constantly adjust technological developments in an effort to improve the quality of education. This is a cycle between technology which is the result of the development of science and education that utilizes technological developments to create new knowledge. According to Juriah & Juanengsih (2016), technology serves as a means to deliver instruction. Technology in education is used by teachers as a facilitator to create meaningful learning to achieve learning objectives. The existence of technology must be interpreted as an effort to increase the effectiveness and efficiency of teaching and learning that meets educational needs, facilitates the learning process and improves the quality of learning (Nurillahwaty, 2022; Nento & Manto, 2023).

The integration of technology in the Constructivist Teaching Sequence model provides a great opportunity to realize more effective learning. This is also an effort to maximize the creation of learning that can facilitate the development of students' knowledge and skills in the learning process. The use of technology is used as a learning medium in understanding the concept of metabolic material in class XII SMA. Metabolic material is a complex and abstract material because it involves various biochemical processes that occur in living things. The use of various tools and technology platforms can make learning metabolism more interactive and easier to understand.

In this study, the integration of several technologies was carried out to maximize learning using wordwall applications, Virtual Lab, Microsoft Powerpoint and laboratory tools. According to Sari (2021), wordwall is an educational game-based application that contains quiz features such as matching, pairing, anagrams, random words, word search, grouping and so on. This media can be designed to increase learning group activities and can also actively involve students in the learning process (Anindyajati & Choiri, 2017). Based on previous research, wordwall applications help improve scientific literacy and understanding of scientific processes (Handarini & Wulandari, 2020) then it can improve children's learning achievement and attitudes towards science and math (Mahnun, 2018); and able to improve students' ability to master the material (Sartika, 2017). Wordwall can be used for entertainment, preparation purposes, training, and reenactment that can sharpen students' insights. The advantages of the Wordwall application according to Lestari (2021), among them are: (1) Able to provide a meaningful learning system and can be followed easily by students, (2) The assignment model can be accessed easily through the gadgets they have, (3) Web-based and free, (4) Wordwall applications can be designed and are creative.

In addition, there is a Virtual Lab application or virtual laboratory which is a computer program that allows students to run simulation practicums via the internet network or without an internet network and can consist of several sets of simulations such as basic flash, animation, and audio. This allows students to conduct experiments remotely at any time. Virtual laboratories are also very useful when some experiments use hazardous materials and risky equipment (Rosli & Ishak, 2022). In line with that, Alvarez (2021) revealed that virtual practicum activities can provide flexibility in the time and place of doing it. Other obstacles such as difficulties in obtaining practicum materials or risks due to hazardous materials can be overcome by virtual practicum activities. In research Arifullah (2020), revealed that education should attach importance to integrating information and communication technology in science learning, to facilitate students in studying scientific phenomena that cannot be studied experimentally due to some barriers such as danger, high cost or lack of time to complete experiments.

Then there is the Microsoft PowerPoint application which is often used in the world of education. This application is used to design presentation materials in the form of slides that can be made in the form of text, diagrams, graphs and others. With the help of this software, students can easily create professional presentations which can be used as learning materials according to their needs. Microsoft PowerPoint features various editing tools such as transitions, animations, images, videos, audio, hyperlinks, diagrams, tables, graphs and others (Kusuma, 2020). Microsoft PowerPoint provides slide facilities to accommodate the main points of discussion that will be conveyed to students. With animation facilities, a slide can be modified interestingly. Likewise, the front picture, sound, and effect facilities can be used to create a good slide. This program can accommodate students who have visual, auditive, or kinesthetic types (Meilinda *et al*., 2014).

Implementing Innovation of Constructivist Teaching Sequences Model on Metabolism Material

The innovation of the Constructivist Teaching Sequences model is done by integrating technology in the learning stages. This is intended as an alternative to learning biology by using the Constructivist Teaching Sequences s model, especially on metabolic material. The stages of the Constructivist Teaching Sequences s model include introduction, exploration, restructuring, application and review (Widodo, 2021). The implementation of the innovative Constructivist Teaching Sequences model using various technologies can be seen in table 1.

Table 1. Innovations in the stages of the Constructivist Teaching Sequence Model using technology

Stages	Students' Activities	Teacher's Activity	Technology
Introduction	Students prepare themselves, their minds, and emotions to be able to learn in a focused and comfortable state by playing games about what they know about enzymes.	The teacher conditions the students to be ready to learn through the random wheel and random card features regarding enzyme material.	*Wordwall*
Exploring students' pre-conceptions	Students work on questions on the Wordwall web related to prior knowledge about the nature, workings and factors that affect the work of enzymes.	The teacher explores students' prior knowledge by giving questions through the Quiz feature.	*Wordwall*
Restructuring the conceptions	Students organize prior knowledge into new construction by conducting a virtual practicum on the catalase enzyme experiment with guidance in the form of worksheet.	The teacher provides information to build students' prior knowledge through catalase enzyme practicum with the worksheet that has been designed.	*Virtual Lab* Kemdikbud

Stages	Students' Activities	Teacher's Activity	Technology
Applying the new conceptions	Students apply the knowledge gained from the experiment using Virtual Lab by applying it through the practicum of catalase enzyme in the biology laboratory with the same worksheet.	The teacher conditions students to apply concepts by applying them to different conditions	Laboratory equipment
Reviewing and evaluating the new conceptions	Students assess the accuracy of new knowledge by presenting the results of practicum and reflection together with teacher guidance	The teacher encourages students to reflect together on the results of the practicum that has been presented.	*Microsoft PowerPoint*

From table 1. it is known that learning is carried out in several stages to condition students to learn. According to Widodo (2021), the learning model actually talks about the stages of thinking that occur in the student's brain, not the stages of the teacher teaching. A learning model has stages that result in the learning process by students so that learning becomes meaningful and achieves learning objectives.

Learning using the constructivist teaching sequences model begins with the initial stage, namely the introduction, where students prepare themselves to focus on participating in learning. Students play the random wheel and random card features on the Wordwall web application guided by the teacher in front of the class. This activity allows to attract students' attention with a light cognitive load even though it contains the material to be taught, so that students are motivated and better prepared to receive learning materials. The teacher has previously prepared question items related to enzyme material and made them in the form of a wheel which is then rotated clockwise and displayed on the white board through the projector. It is said in the research (Sari, 2021), The teacher can also customize the game settings such as the number of rounds, duration of rounds, and adding or subtracting question items. The game can also be shared via a link to students to play online. The appearance of the games in the introduction stage can be seen in Figure 2.

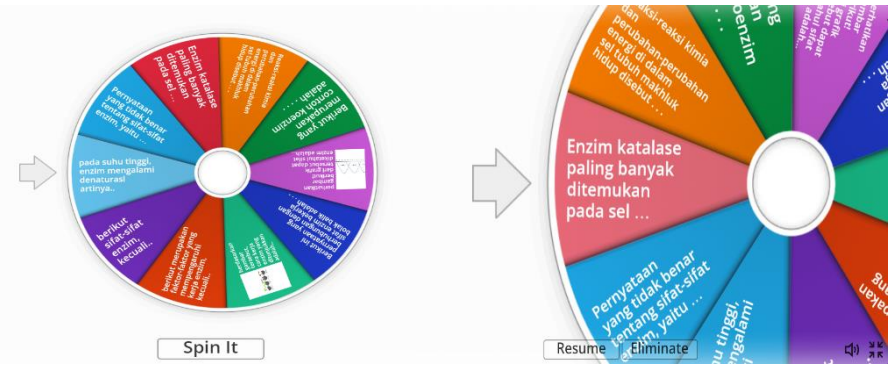

Figure 2. Display of Word Wheel feature usage on Wordwall website

The second stage is exploration, where students activate their prior knowledge through quizzes about the nature, workings, and factors that affect the work of enzymes. This activity is carried out through the wordwall application with the Quiz feature that has been previously designed by the teacher. At this stage students do the activity individually, so that the teacher can see how deep the students' initial knowledge of the material taught. The quiz consists of question items along with answer choices which will then be answered by students through their respective accounts. After students complete the quiz, students and teachers can see the results. This can be an overview of students' initial knowledge of the enzyme material and can help teachers to maximize core learning.

Figure 3. Display of Quiz feature usage on Wordwall website

The third stage is restructuring or reconstruction, at this stage students are invited to do a virtual catalase enzyme practicum through the Virtual Lab Kemdikbud application. The teacher facilitates the formation of student knowledge by providing practicum instructions (worksheets) that are in accordance with the practicum being carried out. The use of Virtual Lab is also intended for students to explore and recognize tools, materials, procedures and objects or phenomena that should appear in an experiment without having to fear failure in carrying out the practicum. This stage emphasizes providing correct information as a new concept to students. Virtual Lab allows students to see an interactive simulation of a reaction involving the enzyme catalase. Students can observe how catalase accelerates the decomposition of hydrogen peroxide into water and oxygen. Students can also control and manipulate experimental variables easily, such as substrate concentration, pH, and temperature to see how these factors affect enzyme activity.

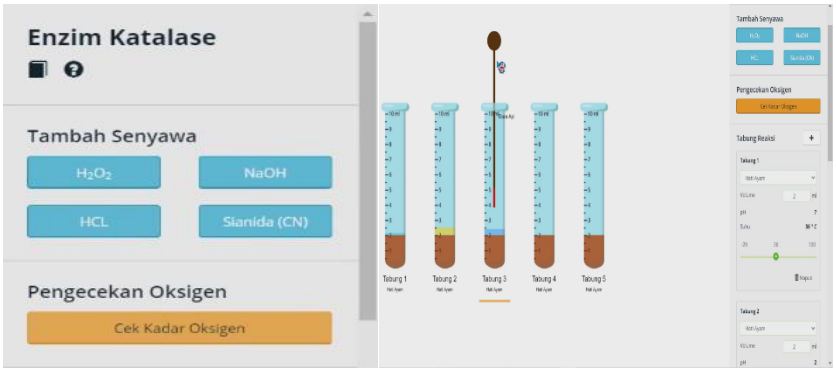

Figure 4. Display of Virtual Simulation of Catalase Enzyme Practicum

The fourth stage is application, at this stage students apply the knowledge that has been formed during the virtual practicum by doing the practicum directly in the biology laboratory with the actual practicum tools. Students are divided into several groups, and conduct experiments with the same worksheet. In this case, students are conditioned to implement knowledge of tools, materials procedures and observations of enzyme activity that have been done before. Students will find differences in the process of finding objects or phenomena that occur in direct observation. This will also increase students' insight into the material being taught. Through direct experiments, students also get the opportunity to apply the theories and concepts they have learned before. Students can also develop science process skills such as observing, analyzing data, and scientific communication. Hands-on practicum also encourages teamwork and collaboration and develops the ability to design and carry out scientific experiments.

The fifth stage is a review of knowledge that has been constructed from observations during the practicum then presented in front of the class using power point technology. Microsoft Office Power Point provides slide facilities to accommodate the main points of

discussion that will be conveyed to students. With animation facilities, a slide can be modified interestingly. Likewise, the front picture, sound, and effect facilities can be used to create a good slide. Thus, it accommodates according to students' learning modalities. This program can accommodate students who have visual, auditive, and kinesthetic types (Setiawan *et al*., 2024). This facilitates students' skills in communicating knowledge gained through observations. The teacher will assess and evaluate the knowledge formed to avoid misconceptions.

From the stages of the learning model described above, it can be seen that when students are faced with new concepts, reconciliation usually occurs with previously acquired knowledge and experience. This may change their beliefs or cause them to ignore the new information. To act as active knowledge builders, students must have the ability to ask questions, explore and assess the knowledge they already have. In the classroom, this theory means encouraging students to use active techniques such as experimentation and the use of authentic data to create knowledge and reflect on their own understanding. Constructivism results in a modification of the teacher's role so that teachers help students in constructing knowledge (Alenezi, 2020).

Conclusion

The learning model is a stage of student learning, where the teacher as a facilitator can carry out learning stages that help students to learn in the classroom. Constructivist Teaching Sequences is a learning model based on constructivism theory, which believes that students are learners who have initial knowledge to be built or constructed through the learning process. The constructivist approach, which emphasizes active learning and student-centered experiences, allows learners to build their knowledge through inquiry, experimentation, and reflection. When combined with technological tools, it fosters greater engagement, improves critical thinking, and supports personalized learning paths. Innovation of the Constructivist Teaching Sequences learning model by integrating Wordwall, Virtual Lab, and Ms. technology. PowerPoint is used as an alternative to implementing this model in learning. This model proves to be effective in making abstract biology topics more accessible and meaningful, leading to better retention and application of knowledge. The innovative teaching sequences can serve as a valuable reference for educators aiming to modernize their instructional strategies and meet the demands of 21st-century education.

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