Bacterial Teaching Material Supplement Based on the Study of Identification of Resistant Bacteria in Leachate at TPA Talumelito as a Virtual Laboratory-Based Digital Learning Resource

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Abstract: Virtual Laboratory is an application designed based on *software* that will help students carry out virtual observations or experiments. This research aims to determine the description of the cadmium-resistant bacteria teaching material supplement as a virtual lab-based digital learning resource and to determine the validity of the cadmium-resistant bacteria teaching material supplement as a virtual lab-based digital learning resource. This research uses *Research and Development (R&D) research* using the ADDIE model up to the stages *(Analysis, Design and Development).* The results of this research are in the form of a virtual laboratory, the virtual laboratory has a profile feature developer which contains researcher and resource data , topics which contain material and results study of resistant bacteria , instructions use containing stages use virtual laboratory application , and let's go to the lab as feature simulation practicum . The content of the virtual lab content based on observations in the laboratory is contained in a topic feature that explains the stages and results of observing cadmium-resistant bacteria. The results of the observations showed four different colonies , a type of gram-positive bacteria in the form of bacilli ,based on identification character resistant bacterial molecules Cadmium metal was obtained from isolates related to *Aquamicrobium lusatiense.* The results of the virtual lab development with content identifying cadmium-resistant bacteria show a media validity value of 92% by category very valid and the material validity value is 93% by category very valid.

Keywords: Aquamicrobiumlusatiense; Development; Resistant Bacteria; Virtual Laboratory.

Introduction

Education is the process of developing knowledge, skills, values, and attitudes through teaching, training, or research. This involves the transfer of knowledge and culture from one generation to the next. Education can take place at schools, colleges, universities, or in informal contexts such as independent study or on-the-job training. According to Yani & Siwi (2020), education is anything that plays an important role in human life. Education is related to activities study teach. Inside activity Study so a learning process occurs.

Education is factor important in build intelligence society. Education contains the learning process. Learning process can achieve If meets 3 factors important, that is participant Educator, educator and resource learning (Patmawati, 2018; Savira, 2022). Apart from that, quality education is important aspect in measure progress something nation. Through good education so can generated source Power superior and qualified human beings as successor generation nation (Wulandari, 2016).

According to Gusmawan et al. (2020), developments in the field technology information and communication can change the learning process from

the "door closed" which is limited by walls wall class become a learning community open, from rote learning become based learning inquiry, of time limited learning become flexible learning. Progress knowledge knowledge and technology give influence to development education in the world, especially in Indonesia. In line with progress technology and information, development in the world of education must experience more changes good too. In connection with p the development of the world of education demands that teachers must know How method packing learning become more interesting and necessary skills participant can also educate facilitated in the 21st century (Kimianti & Prasetyo, 2019).

Teachers in the 21st century need prepared to improve quality competence himself supported technology, so happen enhancement quality education. That thing because at the beginning the 21st century happened change revolution industry become revolution industry 4.0 (Nalasariet al., 2021). According to Pane & Dasopang (2017), learning is a process while the learning process involves a series of steps and is characterized by interaction between teachers and students which aims to achieve understanding and mastery of the learning material. This process involves several key elements such as: learning objectives, organizing material, preparing learning tools, interaction and communication, as well as evaluation and feedback.

Biology learning at Senior High School (SMA) has related learning elements, namely concepts, theory and practicum or direct observation to make it easier for students to understand the material. Biodiversity material is more specifically bacterial at the level SMA includes material in the odd semester of class microorganisms like monera, protista, fungi and animalia are studied in microbiology. Microbiology namely one branch knowledge in studying biology life Microorganisms and their role in life humans (Qomariyah, 2018). Microorganisms including protozoa,microalgae, fungi (mushrooms), lichens, bacteria and viruses (Anggrini et al., 2023).

According to Ereshefsky (2007) inSetyanto (2016), taxonomy biology role in sorting something species to in something group certain levels classification, and provide principles for classifying taxa to more taxa specific. To achieve these learning objectives, teaching and learning activities must be carried out that can help students understand and learn the material.

Learning activities are a process or interaction carried out with the environment, resulting in changes in behavior related to cognitive, affective and psychomotor aspects. The learning process involves the roles of teachers, students, and learning resources. In the

learning process teachers should be able to process and present material that is easily understood by students in order to achieve learning objectives. For example, in conveying biological material, especially biodiversity material in grouping living creatures (Haedar et al., 2016).

In addition, education also involves factors such as a supportive learning environment, diversity in teaching methods, and attention to students' individual needs. Modern education also integrates technology in the learning process, such as the use of computers, the internet and educational software to enrich students' learning experiences. It is important to remember that education and the learning process can vary depending on the cultural context, educational system, and educational approach applied. An effective educational approach aims to prepare students with skills and knowledge in the era of digital developments or Industrial Revolution 4.0.

Era 4.0 is a term that refers to the current period which is characterized by the rapid use of digital technology and the use of data in various aspects of life. This era is also known as Industrial Revolution 4.0 or Digital Revolution. Technological developments such as artificial intelligence, cloud computing, internet of things (IoT), robotics and big data have changed the way we work, interact and live.Era 4.0 education is in harmony with the industrial revolution 4.0, which aims to create creative and innovative opportunities with the help of technology (Doringin et al., 2020). In Era 4.0, education has focused on conveying knowledge orally or in writing, with the dominant role of teachers in teaching and students as recipients of information. However, with advances in technology and development of society, education has undergone significant changes. Era 4.0 has a significant impact on various sectors, including education.

Education in Era 4.0 aims to produce individuals who are ready to face the demands and challenges of a world driven by digital technology. This requires the adoption of technology in the learning process, curriculum changes, and innovative approaches to teaching and learning. In the educational context, Era 4.0 encourages the use of digital technology to increase accessibility, flexibility and quality of learning. Some examples of the use of technology in education include the use of mobile devices, online learning, the use of digital-based learning applications and platforms, the use of simulations and virtual reality, and the use of data analysis for monitoring. Based on the previous description, Era 4.0 plays a very important role in the world of education (Putriani & Hudaidah, 2021).

Education in the Revolution 4.0 era has experienced many changes in all learning factors, including the use

of learning methods, learning processes, learning media and even learning resources. Education in the era of industrial revolution 4.0 is more focused so that students areable to think critically, creatively andcommunicativelyin the teaching and learning process. The availability of learning facilities that suit students' needs in studying material is very importantespecially in bacterial material, it is material that is closely related to activities practicum, at school Intermediate Top in general Still very not enough do activity practical material on bacteria because limitations inside facilities laboratory form tools and materials will be used, therefore, teachers are expected to be able to facilitate and overcome matter one way is by utilizing digital learning resources as alternative for students in learning and doing activity practicum to achieve learning objectives.

According to Fuada & Wibowo (2016), basically learning media is one model of approach to help know, understand and analyze phenomena certain ones exist in something field science. Besides that, one of them principles of learning media is unlimited used at the time anytime and anywhere by anyone who wantsoperate. Apart from that, Isti'anah et al. (2018) also added that a learning process need supported by sources developed contextual learning.

Based on the description above, the use of digital learning resources is very necessary to increase students' knowledge, skills, interest, and facilities that will support activity practice in studying biodiversity material, more specifically bacteria. According to Supriadi (2015), learning resources are all sources including messages, people, materials, tools, techniques and settings that students can use to facilitate learning activities and improve learning performance.Learning help technology basically is applied learning methodology that can create nuances reformist learning, esp in giving help according to conditions biological and psychological participant education (Andi, 2014; Gaol, 2022).

Development of learning media digital based is expected can help participant educate in increase results Study participant educate. Learning using learning media possible participant educates to focus on content. Learning media load media elements in general complete which includes animated audio, video, text, and possible graphics users to interact in a way interactive through available features (Suranti, 2020).

According to Ramdani (2020), using Android as a learning medium can become alternative as well as solution to create participant educate more active in the learning process. The more active participant educate will influence the results learn.

The minimal use of learning resources will affect student learning outcomes. With the availability of appropriate learning resources, it is hoped that students will be able to explore information about the subject matter, in this case biodiversity material, especially bacterial material. to support students in understanding the material so that researchers have innovations to utilize digital learning resources based on virtual laboratories. This is in accordance with Ahdan et al. (2021) that also needs to be developed a learning model that can combine teaching materials that suit the characteristics of the material so that learner can maximizing use system learning digitally.

According to Sumargo & Yuanita (2014), Virtual laboratory is an experimental activity or observation in the laboratory using *software*. Virtual laboratory refers to a learning environment where students can carry out experiments and practice through digital simulations, rather than through physical equipment in conventional laboratories. According to Ashel etal. (2018), a virtual laboratory is a series of activities carried out virtually using a computer. Virtual laboratories are able to overcome shortages of tools and materials when carrying out real practicums.According to Nurmawati et al. (2022), the current condition of virtual laboratories is like that fast its development. Learning era 21st century today by creating Virtual Reality based virtual laboratories can help participant educate in the learning process digitally that can be accessed anytime, and anywhere connected to the internet.

Virtual laboratories have many advantages compared to real laboratories. There are several advantages to using virtual laboratory-based learning resources: Accessibility: With virtual laboratories, students can access and use them from anywhere, at any time as long as they are connected to the internet. This allows students to study independently without being limited by time and place. Safety and costs: Virtual laboratories reduce risks to student safety and also reduce the costs associated with building and maintaining physical equipment in conventional laboratories. Flexibility and repetition: In a virtual laboratory, students can repeat an experiment or practice as many times as they want. They can change parameters, observe results directly, and understand concepts better through repeated experiments. Technology integration: Virtual laboratory-based learning resources can be integrated with other technologies, such as AI and real-time simulations. This provides a more immersive and interactive learning experience for students. Better visualization: In virtual laboratories, students can see better simulations and visualizations, including clear graphical representations

of phenomena that are complex or difficult to understand in real life.

Although virtual laboratory-based learning resources have many advantages, it is important to remember that hands-on experience in a physical laboratory also has important educational value. However, the use of virtual laboratories can be a valuable addition to enrich student learning and allow broader access to laboratory experiences.

The digital learning resource in the form of a virtual laboratory developed by researchers contains material that can improve understanding, broaden students' insight and provide simulations for students in carrying out online practicums.In fulfilling the content of virtual laboratory-based digital learning resources that will be used during the learning process biology of bacterial material then it can carried out observation activities or study of one of them study resistant bacterial material to cadmium metal. Bacteria is one of them capable microorganisms utilize metal ions one of them is heavy cadmium metal inside activity its metabolism. To get results study associated bacteria resistant to cadmium require test sample. One test samples are available used to reveal resistant bacteria to Cadmium metal viz leachate in landfills. Gorontalo Province has One Place Disposal End Trash and bins leachate reservoir.

Leachate is water produced from rainwater seepage that enters landfills. Leachate is a factor in the development of bacteria because it contains various carbon nutrients and other substances from waste.The bacteria produced from the observation process will be used as a digital learning resource to help students develop and enrich the quality of learning in understanding material related to bacteria.

Based on the previous description, by utilizing virtual laboratories, we are able to develop, enrich students' insight and knowledge and their interest in learning , as well as help teachers in facilitate participant educate in do practicum. Apart from that, the use of learning resources that explain this material should be put to good use by teachers and students because there are many positive elements that arise. It is also hoped that the use and utilization of these learning resources can support the development of knowledge and mastery of bacterial material.

Based on the background described, the researcher will conduct research with the title "Supplement for Bacterial Teaching Materials Based on the Study of Identification of Resistant Bacteria in Leachate Water at Talumelito Landfill as a Virtual Laboratory-Based Digital Learning Resource".

Method

The type of research is development research or *Research and Development (R&D)* using the ADDIE *(Analysis, Design, Development, Implementation and Evaluation) model.* According to Sumarni (2019), R&D research is all processes used to develop and validate a product in the form of *software* or *hardware.* The reason researchers chose this model is very systematic, namely consisting of Analysis *(Analyze)*The analysis stage consists of 2 stages, namely the needs analysis stage and the virtual laboratory analysis stage. Needs analysis in the form of relevant materials and learning resources to be used.

Next, an analysis is carried out from the virtual laboratory, this will make it easier for researchers to determine the concepts and material that will be included in virtual laboratory-based digital learning resources, thenDesign at the design stage *is* the stage where the researcher creates a virtual laboratory-based digital learning resource framework design which will be developed based on the results of the analysis that has been carried out previously. This design stage is divided into two, namely carrying out a study on the identification of cadmium-resistant bacteria as content in the application. and the virtual media laboratory design stage, and the thirdDevelopment *(Development)* in the development stage or *development* of digital-based biology teaching material supplements that have been produced will be validated by material expert validators and media experts , however in this research it is limited to the development stage *(Development),* this is carried out according to the researcher's need to know the level of validity of the digital learning resource products that will result from the research. For the next two stages, namely implementation and evaluation, researchers hope that there will be further research related to the implementation and evaluation of these digital learning resources.

The data analysis technique in this research uses validation scoring on a Likert scale with a score range of 1-4 (Yazid, 2016) and validation criteria using validation criteria with the category very invalid-very valid (Kusumiyati & Ariesta, 2018). The data that was previously obtained was then analyzed using a validation equation 1.

$$\text{Validation} = \frac{The\ sum\ of\ the\ total\ score\ of\ each\ aspect}{\sum\ Max\ Score} X\ 100\% \quad (1)$$

Table 1. Likert Scale Table

Evaluation		Value/score
Very Valid		5
Valid		4
Fairly Valid		3
Less Valid	2	
Invalid		1

Table 2. Validation Criteria

Percentage (%)	Category
81-100	Very Valid
61-80	Valid
41-60	Fairly valid
21-40	Invalid
1-20	Very invalid
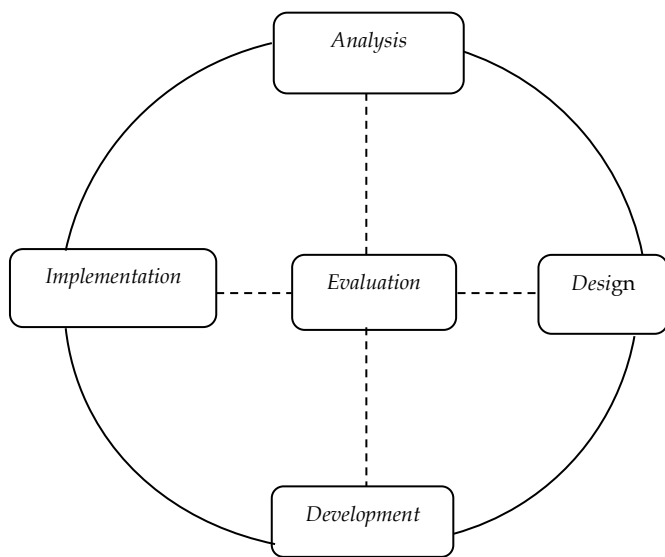
Figure 1. Scheme Steps ADDIE research

Resultsand Discussion

The research results are divided into the results of identifying cadmium-resistant bacteria in leachate as a supplement to bacterial teaching material which will be published in the virtual laboratory application and the results of media validation from material expert validators and media experts.

Description of Bacterial Teaching Material Supplement Based on Study of Identification of Cadmium Metal Resistant Bacteria in Leachate Water as a Virtual Lab-Based Digital Learning Resource

The virtual laboratory application consists of the main display section of the application which contains the name of the virtual laboratory application, and selected features which include: developer profile, topic, instructions for use, and simulation (let's go to the laboratory) (Figure 2).

Figure 2. Laboratory Virtual Display Design

The data obtained after making observations in the laboratory is loaded into the virtual laboratory. The virtual laboratory has a main page which contains features, instructions for use, developer profile, topics and simulations. Let's go to the lab. To reveal the results of observations in the laboratory, it is included in the topic feature. Content contained in the form of videos, materials and images. As for the results of the content, it was found that through laboratory identification of resistant bacteria in leachate, 4 different bacterial isolates were obtained with the morphological characteristics of the isolates, namely red, yellow, white and orange, round shape, smooth edges and raised surfaces (Figure 3). Cadmium resistant bacterial isolates were able to grow on media containing ≥ 5 ppm heavy metals, after isolation on media containing cadmium with concentrations of 0.175 ppm, 0.2 ppm, 0.210 ppm, 0.225 ppm, 0.25 ppm, the four isolates were unable to grow at a concentration of 0.25 ppm but there was one isolate that was able to grow on media containing a cadmium concentration of 0.210 ppm. Through a resistance test, gram staining was then carried out, the results of the gram staining of isolate B included gram positive bacteria in the form of bacilli (Figure 4).
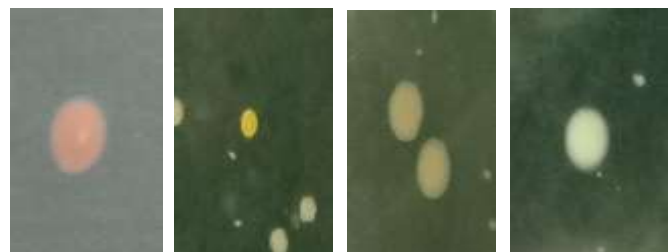

Figure 3 . Colony Morphology of Cadmium Resistant Bacteria

Figure 4. Cadmium Resistant Bacteria Gram Stain

The results of molecular identification through the stages of DNA extraction, 16S RNA Gene Amplification, 16S rRNA Gene Sequencing, DNA extraction using absorbance wavelengths of 260 and 280, the pure DNA value produced was 1.9. According to Dewanta & Mushlih (2021), DNA purity is measured using absorbance wavelengths of 260 and 280 nm, a good purity value ranges from 1.8-2.0. Furthermore, the results of the DNA extraction were amplified using PCR and electrophoresed with 16S rRNA using primers 27F and 1492R, successfully duplicating the 16s rRNA gene in the 1,500 bp DNA band, this indicates an indication of success in the DNA amplification results. The next result was 1430 PB and there were 10 blast results that were more closely related to the isolate, isolate B2 was more closely related to *Aquamicrobium lusatiense* , this was proven by the phylogenic tree. According to Jeong et al. (2022), *Aquamicrobium lusatiense* bacteria are gram-negative bacteria found in environments full of pollutants such as waste water treatment plants, active waste sludge, biofilters, plains contaminated with oil, and soil contaminated with chlorobenzoate.
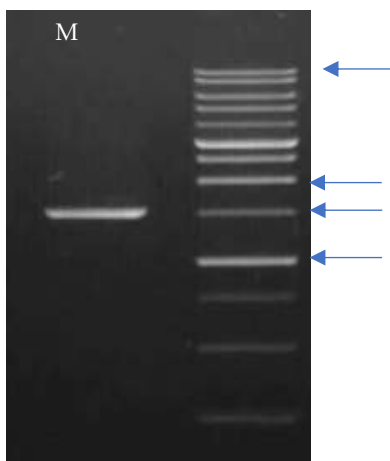

Figure 5 . Electrogram results of the 16S rRNA gene of primary cadmium resistant bacterial isolates 27F and 1492R
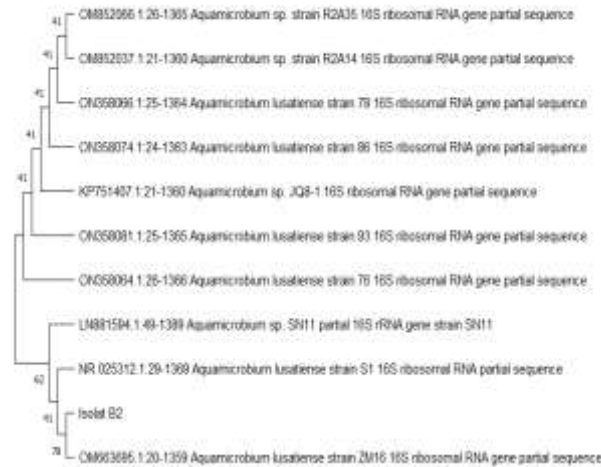

Figure 6. Phylogenetic tree of B2 isolates using the Neighbor-Joining construct with a boostrap of 1000 x

Description of Virtual Laboratory Application Validity Results

Product validity is carried out to obtain results from the virtual lab feasibility. Based on validation of laboratory virtual media by material expert validators, the average percentage result was 92% with a very valid category (Figure 7) with the assessors for each aspect being in the 4-5 value range (Table 3). Meanwhile, based on validation of laboratory virtual media by material expert validators, the average percentage result was 93% with a very valid category (Figure 7) with the assessors for each aspect being in the 4-5 value range (Table 4).
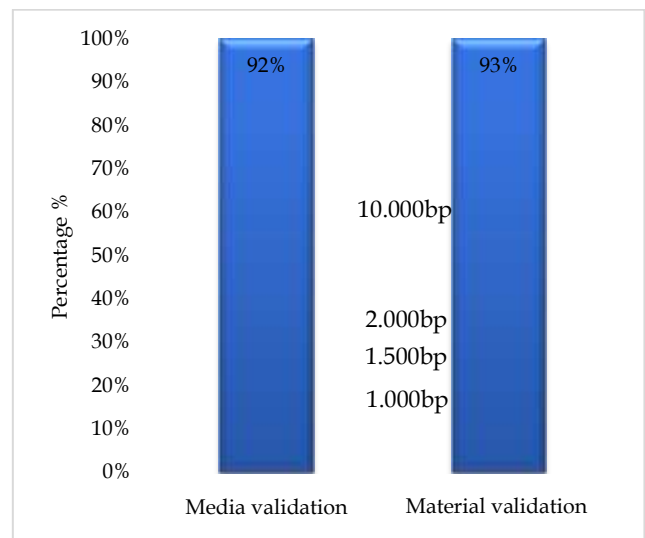

Figure 7. Virtual Lab Validity Percentage Results

Learning using digital learning resources is one of the uses in the form of information technology. As a digital learning resource, the virtual laboratory application not only displays material as learning material, but this application also contains material in text form combined with appropriate images, video and

audio, then through this application students can carry out practicums or live simulations. how to identify or characterize bacteria via cellphone. Presenting messages or materials using words and images will produce better learning. Animated images and videos in virtual laboratory applications can make it easier to convey things that are difficult to convey in words and can provide a stimulus for students to relate them to real situations. According to Widi and Sulistyowati (2014), explained that virtual laboratories can attract students' interest in learning so that it can make it easier for students to understand the material that will be presented, besides that virtual laboratories are effective and easy to use.

Table 3. Material Expert Validation Results

Validation Aspect	Score				
	1	2	3	4	5
Relevance of Material					
Accuracy of content (material)				✓	
Depth of material				✓	
Suitability of image to material					✓
Suitability of simulation to material				✓	
Coverage of benefits					
Helps the learning process					✓
Provides focus of attention					✓
Language Quality					
Use of language well and correctly					✓
Suitability of language that is easy to understand with target use					✓

Table 4. Media Expert Validation Results

Validation Aspect	Score				
	1	2	3	4	5
Software Engineering (Development).					
Accuracy of *software selection* for virtual laboratory development					✓
Ease of use (*usability*)				✓	
Application system reliability (*reliable*)					✓
Visual Communication (Display)					
Simple and attractive appearance					✓
Quality and suitability of Photos, Images and Graphics				✓	
Video and Audio Quality					✓
Animation Quality					✓
Navigation consistency and interactivity					✓
Text type and size					✓
Text readability in virtual laboratory applications				✓	
Interest in using virtual laboratory applications					✓
Laboratory virtual display design				✓	
Clarity of instructions for use				✓	

The virtual laboratory application was designed using the Unity application, and for image design using the Photoshop application, while the video was designed using the video premiere application. There are several stages carried out in designing a virtual lab application, the first is designing the concept that will be created including application design,images, videos and determine the structure and concept of the material.A virtual laboratory application that has been declared valid and suitable for use by studentsLearning Activities. Very good qualifications are obtained because the virtual laboratory application meets the rules of learning media which include accuracy of material content, suitability of material, suitability of images, use of language, and quality of the application which includes quality of images, graphics, animation, video, sound, text, usabilityand *reliable.* Media can provide a more concrete understanding to students, this can be done by designing material by combining many elements in the application, one of which is interactivity so that it can make the learning process more interesting and effective because it involves more than one sense in learning so it can stimulate students to understand the material presented through video, image and material features in the virtual laboratory application.Based on research conducted by Muhajarah& Sulton (2020), the virtual lab application has validity by category very valid, learning use virtual laboratory application own huge impact significant to participant educate. Whereas based on results research conducted by Yeni & Yokhebed (2015), virtual laboratory application can increase results research.

Conclusion

Based on the description of the results that have been discussed, a bacterial teaching material supplement was developed in form source virtual laboratory- based digital learning which has 4 features ie feature profile developer, features topics, features instruction usage , and features Come on to the lab. The bacterial teaching material supplement based on a study of the identification of cadmium metal resistant bacteria in leachate at the Talumelito landfill has a validity level of 93% for material experts and 92% for media experts in the categoryvery valid.

Author Contributions
Conceptualization, W.D.U, Y.R, A.H.M, S.S.K, and L.D.; methodology, W.D.U, Y.R, A.H.M, S.S.K, and L.D.; software,

Conflicts of Interest
The authors declare no conflict of interest

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