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Development of Augmented Reality (AR) Learning Media to Increase Student Motivation and Learning Outcomes in Science

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***Abstract**:* This research aims to 1) develop AR learning media regarding the interaction of living things and the environment, 2) determine the feasibility and response to AR media, and 3) determine differences in students' motivation and science learning outcomes before and after implementing AR media. AR-based mobile application. The study of AR media development uses the Waterfall development model which consists of 5 stages, namely analysis, design, code, testing, and maintenance. In-depth research data collection techniques use observation sheets, interview guides, media expert and material expert validation questionnaires, student response questionnaires as well as science learning motivation questionnaires and cognitive tests. The learning trial used a quasi-experimental design method with a research pattern using a nonequivalent control group pretest and posttest design involving 2 classes, namely class VII-C as the control group and VII-D as the experimental group. The results of the research show that 1) AR-based mobile applications can be used anytime and anywhere, the resulting applications are equipped with animations, games, and 3-dimensional and 2-dimensional images, 2) the product is valid and AR-based AR-based mobile applications are suiTabel for testing and response results in students towards AR-based mobile applications received a very good response from students, 3) learning using AR-based mobile applications can increase learning motivation and student learning outcomes, especially in the subject of interaction between living things and the environment.

***Keywords**:* Augmented Reality, Waterfall Models, Learning Motivation, Learning Outcomes

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INTRODUCTION

Learning media is a tool used to convey material so that the teaching and learning process runs effectively and efficiently. The main advantage of learning media is that it influences the climate, environment, learning process and, learning conditions created by the teacher (Ntobuo et al ., 2018; Nur et al ., 2017). The use of learning media can also increase students' in-depth understanding of a topic in learning (Aulia et al ., 2019; Dewantara, 2019; Hartini et al ., 2017; Rahman et al ., 2017; Safaruddin et al ., 2020). One tool that can be used as a learning medium is a smartphone.

A smartphone is a mobile device that is equipped with an operating system like a computer (Ismanto et al ., 2017). Maknuni (2020) said that smartphones have the advantage of enabling computing processes so that they can be integrated with various human activities without being limited by space and time, this is what can attract the attention of users. Based on the latest data published by Hootsuite in Paridawati et al. (2021), it is stated that in January 2018 there were 177.9 million Indonesians who were active smartphone users out of a total population of 265.4 million people. Worse yet, in 2020, of Indonesia's total population of 272.1 million, there will be 175.4 million active smartphone users. This is confirmed by a survey conducted by the Ministry of Communication and Information supported by UNICEF in Nurningtyas & Ayriza (2021) that smartphone users in Indonesia in 2018 were ranked as the third largest smartphone users in the Asia Pacific. Apart from that, teenagers aged 13 to 18 are the most smartphone users, namely 80% of smartphone users in Indonesia (Irawan, 2021). The large number of smartphone users in Indonesia is based on several reasons, namely smartphones have quite high processors, quite large storage memory and additional RAM like those on PCs or laptops (Akmal & Susanto, 2018) . Asri (2019) in his research informed that the advantages of smartphones are that they have high mobility can be operated more effectively and are integrated with augmented reality (AR) media. Augmented reality (AR) is a technology that can combine 3D objects into a real environment (Romadhon et al., 2017; A. Syawaludin et al., 2019; Yesmaya et al., 2018). Nugroho & Pramono (2017) stated that the combination of 2-dimensional and 3-dimensional virtual objects in a real environment, then projecting these virtual objects for a certain time is called AR. Haryani & Triyono (2017) confirmed that AR is part of the virtual environment (VE) or what is usually called virtual reality (VR) because AR gives users an overview of the real world and the virtual world seen from all places. AR has the characteristics of being interactive, real (real-time), and in 3 dimensions (Rahmat & Yanti, 2020). Fakhrudin & Kuswidyanarko, (2020) said that AR can be accessed via the Android OS found on mobile phones. Pratama et al. (2020) emphasized that AR can be operated with mobile devices such as smartphones, Tabelts and, so on so that students can directly interact with AR objects. AR media development is supported by several other applications such as Blender, Vuforia, Unity, Figma, Visual Studio Code, and programming languages such as C Sharp, C++, Python, and Java.

Pratama (2020) in his research said that the application of AR can increase student activity, increase student interest, and help teachers in delivering learning material. AR is very effective and efficient when applied to learning (Affriyenni et al., 2020). Ismail (2019) emphasized that the application of AR-based learning media can improve students' conceptual and contextual understanding, as well as students being more active in learning activities in independent learning without a teacher. Furthermore, the advantages of AR media on learning are that it influences the climate, environment, learning process, and learning conditions created by the teacher (Ntobuo et al ., 2018; Nur et al ., 2017) and can increase students' motivation and learning outcomes (Areni et al., 2017). ., 2018; Husna et al., 2017). Apart from that, AR media can increase students' conceptual understanding of a learning material topic (Aulia et al ., 2019; Dewantara, 2019; Hartini et al., 2017; Rahman et al ., 2017; Safaruddin et al ., 2020).

Based on the results of surveys and observations carried out at SMPN 3 Jombang 1) understanding of the concept of interaction between living things and the environment is still low due to the lack of use of learning media. 2) Learning about the interaction of living things and the environment is still delivered using conventional methods and teachers rely heavily on textbooks to organize and deliver learning material. 3) Teachers tend to invite students to read and understand theory without help and direct interaction with learning media, making it difficult for students to understand theory directly, especially regarding the interaction of living things and the environment. In line with Anggraini et al. (2022) it is known that problems in Ponorogo City Middle Schools are often faced by students during the implementation of learning activities, one of which is that students tend to lack understanding of important things in the material that the teacher conveys. (Fitri et al., 2019) emphasized that in the city of Bandung, the problem that occurs is the lack of mastery of concepts among students, namely the concepts that are often given to students concepts that do not come from the students' own concepts (ideas), but rather concepts taken from books and ideas. teachers so that the achievement of concept mastery is less than optimal. Furthermore, from teacher's own factor, namely that teachers do not have the skills to innovate and be creative in aspects of developing their learning media. This is in line with the results of interviews with science subject teachers at the Jombang Regency Science Subject Teachers' Deliberation Forum (MGMP IPA), where information was obtained that there was no use of learning media in the learning process due to the limited ability of teachers to create and apply innovative, creative, learning media. and easy to apply by students. However, the absence of learning media in science learning is not only the teacher's fault. This is in line with research by Yuliono et al. (2018) which informs that the lack of variety in learning media is not solely due to the teacher's fault but is caused by a lack of science learning time, school conditions (facilities and infrastructure), and student characteristics, and less than optimal development of existing technology.

This research aims to 1) develop AR learning media regarding the interaction of living things and the environment, 2) determine the feasibility and response to AR media, and 3) determine the differences

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in motivation and science learning outcomes of students before and after applying AR media. AR media was developed based on Basic Competencies (KD), indicators, and learning objectives in the material on the interaction of living things and the environment in class 7 of the 2013 curriculum. Furthermore, AR media was designed in such a way as to be able to help students understand and provide an overview related to the theory of the interaction of living things and the environment. This media can be accessed and used easily by teachers and students using smartphones in the science learning process. The hope is that AR media is suiTabel for use and becomes a new learning media in increasing students' motivation and learning outcomes in science learning.

METHOD

This research is research and development research. In this research, researchers focused on developing product-oriented augmented reality (AR)-based learning media. AR media is aimed at Grade 7 Middle School (SMP) students in the form of a mobile application that contains science learning material that discusses the interaction of living things and the environment. The development model used is the waterfall model. The waterfall model was chosen because this model provides a systematic software life flow approach, where each stage of activity must be completed properly before moving on to the next stage (Irwanto, 2021). This is in line with Melinda et al. (2021) who said that the waterfall model is a systematic model starting from the analysis stage to maintenance. This model procedure consists of 5 stages, namely analysis, design, code, testing, and maintenance (Irwanto, 2021; Melinda et al., 2021; Sommerville, 2016). Sommerville (2016) states that analysis includes constraint analysis activities, and system objectives are determined through consultation with experts. Davis (2014) emphasized that the analysis stage includes the tools that will be used in creating a system. Design is a multistep process that focuses on program creation design including data structures, device architecture, representation, and coding procedures (Hardiyanto et al., 2019). Andriansyah (2018) emphasized that this stage translates the needs from the previous stage into a design representation so that it can be implemented in the next program. Code is carried out to translate documents (software requirements) into programs using programming languages such as C sharp (C#). The results at this stage are in the form of a computer program that matches the design that has been created(Andriansyah, 2018; Sidik et al., 2020). Testing is carried out on software that has been created from a logical and functional perspective and ensures that all parts that have been designed and created are running according to plan (Ramdhani & Mutiara, 2020; Sidik et al., 2020). Maintenance is carried out periodically in managing a device so that the device will run well (Saputri & Eriana, 2020). This stage can lead to repetition of the software development process from specification analysis to device changes, but not to creating new software. AR media development design using the waterfall model as shown in Figure 1 (Sommerville, 2016; Sutresna & Yanti, 2020).

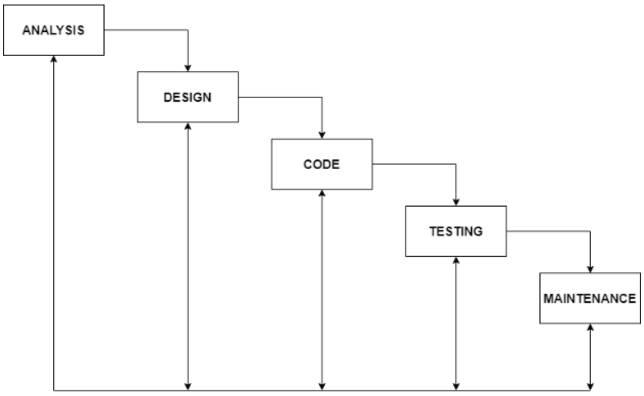

Figure 1. Waterfall Development Model Development Procedure

The product developed in this research is AR-based science learning multimedia in the form of a mobile application to increase student motivation and learning outcomes. The resulting mobile application contains components including animated videos, 3-dimensional and 2-dimensional animation, images, text, and *games* to train students' knowledge. Before being tested, the AR-based mobile application product was validated by media experts and material experts, and tested the response

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to the resulting product. The validation test aims to determine the feasibility of AR-based media by material expert validators and media experts consisting of science lecturers and teachers, each with 10 experts. Meanwhile, the test of student responses to AR media aims to determine the results of student responses regarding the media that has been developed, totaling 30 students at SMP Negeri 3 Jombang class VII- A, even the semester of the 2021/2022 academic year.

Next, the AR-based mobile application product was tested in the learning process in class VII-C as the control class and VII-D as the experimental class. The trial was carried out using the quasi-experimental design method with a research pattern using a nonequivalent control group pretest and posttest design involving an experimental group and a control group which are presented in Tabel 1 (Endris & Suhartini, 2022).

Tabel 1. Design of Nonequivalent Control Group Pretest and Posttest

Group	Pretest	treatment	Postets
Control	O1	-	O2
Experiment	O3	X	O4

Description: O1 is learning motivation and learning outcomes at the beginning of learning science in the control class, O3 is learning motivation and learning outcomes at the beginning of learning science in the experimental class, O2 is the final ability in learning science in the control class, O4 is the final ability in learning Science experiment class, and X is learning science using an AR-based mobile application.

Data, Instruments, and Data Collection Techniques

This research obtained data in the form of numbers (quantitative) which will then be converted into qualitative. Qualitative data were obtained from the validation results of material experts and media experts, student responses after using AR-based mobile applications, student learning motivation and student learning outcomes. The types of data obtained in the study consisted of a) assessment and validation of AR-based mobile applications from media experts and material concepts obtained from material experts, b) student responses after using AR-based mobile applications obtained from questionnaires provided, c) effectiveness of AR-based mobile application on increasing learning motivation, and learning outcomes of students in science learning material on the interaction of living things and the environment.

The data collection techniques used in this study were non-test and test techniques. Non-test techniques include interviews, observations, questionnaires, and documentation, while test techniques include pretest and post-test questions. Interviews were conducted to obtain information related to research to be carried out in schools regarding school needs related to learning media and the availability of resources. Subjects in this interview were school principals, vice principals for curriculum, and science subject teachers. Observations were made to find out how the condition of the school includes facilities and infrastructure, especially when learning is carried out, and the characteristics of students. The questionnaire used in this study aims to 1) obtain product feasibility data consisting of media experts and material experts who are competent in their fields; 2) obtain response data after using AR-based mobile application media before being tested in classroom learning; 3) obtain data on students' motivation to learn science from the pretest and posttest applied to AR-based mobile applications; 4) documentation is carried out with the aim that research activities are carried out according to the concepts prepared in the hope that the research results will be clearer and more accurate. Tests are used to collect data regarding the improvement of student learning outcomes. The type of test used is multiple choice consisting of 15 questions and essay consisting of 5 questions. The tests were conducted on students who used AR-based mobile applications in the science learning process (experimental class) and students who did not use mobile applications in the science learning process (control class). The pretest was carried out to determine the initial abilities of the experimental class and the control class, while the posttest was used to determine the effect of AR-based mobile applications on student learning outcomes.

The data collection instruments used in the research were 1) interview guides consisting of several questions to gather initial information related to the facts of learning science at SMPN 3 Jombang and analyzing the needs of learning media that are often used in learning science. Respondents in this interview were school principals, vice principals for curriculum, and science subject teachers. 2) Material expert validation questionnaire sheets consisting of 7 aspects namely content quality, learning

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goal alignment, feedback and adaptation, motivation, content feasibility components, linguistic components, and presentation components. Material expert validation questionnaire was adopted from (Nesbit et al., 2009) and adapted from (Arsyad, 2013). 3) The media expert validation questionnaire sheet consists of 6 aspects, namely appearance design, user interaction, accessibility, aspects of content quality and objectives, instructional quality, and technical quality.

Media expert validation questionnaire sheet adapted from (Nesbit et al., 2009) and (Prasetiyo & Perwiraningtyas, 2017). 4) Student response questionnaire sheets which contain 5 aspects namely ease of use of media, time efficiency, benefits of use, independent learning, and attractiveness adapted from (Lahra et al., 2017) and (Widiastika et al., 2021). On the student response sheet, there are positive statements (favorable) and negative statements (unfavorable) totaling 20 items, where each statement consists of 10 positive statement items and 10 negative statements. Student response questionnaire sheets before use must go through expert validation in their field. The validation results of the student response questionnaire sheets were 0.798 with a high category, it can be concluded that the student response questionnaire sheets were appropriate for use. 4) Learning motivation questionnaire sheet, totaling 32 statements. The motivational questionnaire was used to determine the pretest and posttest learning motivation of AR-based mobile applications in the control class and experimental class, before being used the motivational questionnaire had to be validated by experts in their fields, namely science education lecturers and Informatics Education at Trunojoyo University, Madura. The learning motivation questionnaire instrument grid was modified from (Glynn et al., 2009) and (Susanti et al., 2021). 5) a test sheet consisting of 15 questions. The test sheet is used to determine the pretest and posttest learning outcomes of the AR-based mobile application in the control and experimental classes, before being used the test sheet must be validated by an expert, namely a science subject teacher, science education lecturer at Trunojoyo University, Madura.

The data collection instrument uses a Likert scale with the gradation of values 1to4 so that the answers to each item in the form of words are 1) strongly disagree, 2) disagree, 3) agree and 4) strongly agree (Sugiyono, 2019). The Likert scale used in the value validation sheet for AR-based mobile application feasibility, student responses and motivation to learn science is the same, but on the Likert scale values for student response questionnaires and learning motivation questionnaires there is a slight modification because on the student response questionnaire and questionnaire there are positive statements (favorable) and negative statements (unfavorable) so that the Likert scale values for negative statements (unfavorable) become 1) strongly agree, 2) agree, 3) disagree and 4) strongly disagree, whereas in positive statements (favorable) is the same as the Likert scale value of the media validation sheet (Cahyani et al., 2020).

Data analysis techniques

Data analysis was carried out with the aim of a) measuring and knowing the feasibility of AR-based mobile applications, b) knowing student responses after using AR-based mobile applications before being applied to science learning in class, c) knowing differences in learning motivation and student learning outcomes in learning Science pretest and posttest using AR-based mobile applications in the control class and experimental class. The results of data analysis are in the form of quantitative data in the form of percentages and qualitative data. Quantitative data includes assessing the feasibility of AR-based mobile applications from media experts and material experts, students' responses after using the product, students' motivation, and science learning outcomes. Quantitative data obtained from a series of assessments will be converted into qualitative data which aims to analyze the quality of AR-based mobile applications, student responses, increased motivation, and student science learning outcomes.

Analysis of product feasibility data from media experts and material experts obtained will be processed using Aiken's V coefficient formula with the following formula formula 1 (Bashooir & Supahar, 2018).

$$V = \frac{\Sigma(S)}{[n(c-1)]} \qquad (1)$$

Information: $S = r - lo$; r= the number given by the appraiser; lo= lowest validation rating score; c = the highest validation rating score; n= the number of experts or practitioners who carry out the assessment; i = integer from 1,2,3 to n

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The interpretation of the results of Aiken's V formula is 0 to 1. Aiken's validation values can be seen in Tabel 2 which has been adjusted to the Aiken's V validation Tabel (Aiken, 1985) for 10 validators.

Tabel 3. Media validation categories

No	Validity Index	Criteria
1.	$V \geq 0.81$	High
2.	$0.731 \leq V < 0.80$	Currently
3.	$V \leq 0.73$	Low

Analysis of student response data after using an AR-based mobile application that has been obtained will be searched for by formula 2 for each aspect (Kurniati et al., 2018) in percentage form.

$$\bar{x}\ tiap\ aspek = \frac{1}{banyak\ responden}\ x\ \frac{\Sigma_1^n X}{n} \ldots\ldots\ldots\ldots \quad (2)$$

Information: Σ_1^n *= total score for each aspect; n = number of statements per aspect*

Meanwhile for the average of all aspects of student response using formula 3 (Kurniati et al., 2018) .

$$\bar{x}\ keseluruhan = \frac{Jumlah\ rata-rata\ skor\ setiap\ aspek}{banyak\ aspek} \ldots\ldots\ldots\ldots \quad (3)$$

Convert the average score that has been obtained on each aspect and overall using a scale of 4 criteria (Admadianti & Irfa'i, 2016) in Tabel 3.

Tabel 3. Student response criteria

No	Range	Categories
1.	> 3.25 to 4	very good
2.	> 2.5 to 3.25	Good
3.	> 1.75 to 2.5	Enough
4.	1 to 1.75	Not good

Data analysis of students' motivation to learn science that has been obtained will be processed including the calculation of each item statement using formula 4 and the average overall motivation to learn science using formula 5 (Kartini & Putra, 2020)

$$\mathrm{P} = \frac{Jumlah\ skor\ hasil\ pengumpulan\ data}{Jumlah\ skor\ kriterium}\ X\ 100\ \%. \quad (4)$$

where P is Percentage per statement item(Kartini & Putra, 2020)

$$\text{Nilai Motivasi} = \frac{skor\ yang\ diperoleh}{skor\ maksimum}\ X\ 100 \ldots\ldots\ldots\ldots (5)$$

Convert the average score that has been obtained on all aspects using the criteria Tabel 4 modification from (Widiastika et al., 2021).

Tabel 4 Categorization of student motivation

No	Value Intervals	Categories
1	$80.1\ \% < NR \leq 100\ \%$	very good
2	$60.1\ \% < NR \leq 80\ \%$	Well
3	$40.1\ \% < NR \leq 60\ \%$	Enough
4	$20.1\ \% < NR \leq 40\ \%$	Not enough
5	$0\ \% < NR \leq 20\ \%$	Very less

Then after converting the average score obtained, the differences in pretest and posttest learning motivation will be calculated respectively in the control class and the experimental class. Lastly, data analysis of pretest and posttest science learning outcomes was analyzed using an application, namely SPSS 20. The test conducted to analyze learning outcomes was a paired t-test *to* determine the increase in science learning outcomes in the control class and the experimental class. Before carrying out the normality test to determine whether the data is normally distributed or not.

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RESULTS AND DISCUSSION

The product in this study is an AR-based mobile application to facilitate understanding of concepts in the interaction of materials of living things and the environment for the grade 7 junior high school curriculum 2013. The presentation of the results and discussion follows the waterfall *development models*.

Analysis Stage

The analysis stage was carried out through interviews and observations of the implementation of the science learning process in grade 7 of SMP Negeri 3 Jombang. These activities include analysis of the curriculum, learning objectives, the potential of students, and analysis of the potential of science teachers. Curriculum analysis is carried out by outlining and understanding the characteristics of the curriculum used in schools, especially the junior high school level, namely the 2013 revised 2017 curriculum. The basic competencies used are KD 3.7 analyzing the interaction of living things and their environment and population dynamics due to their interactions and KD 4.7 presenting the results of observations on the interaction of living things and the surrounding environment for class VII SMP. Next, examine basic competencies (KD) to formulate learning indicators and learning objectives that will be integrated into AR-based mobile applications.

Analysis was also carried out to analyze the characteristics of students. Analysis of student character was obtained through interviews and observations with school principals, and vice principals for curriculum and science teachers. The results of the interviews and observations are 1) the lack of use of learning media, 2) the use of learning media only depends on the creativity of the teacher, 3) the understanding of students' concepts on the material interaction of living things and their environment is lacking, 4) students are more interested in using learning media during the learning process and 5) students are more motivated when the learning process uses learning media. On the other hand, interviews and observations resulted in the conclusion that science subject teachers have the potential that be utilized in learning such as guiding and facilitating students to improve skills, knowledge, and attitudes. One of these potentials is the ability to operate *smartphones* among teachers (Usmaedi et al., 2020) which includes using mobile applications.

In the analysis phase, there are device requirements analysis activities, device requirements analysis is the initial activity of the development life cycle of a software (learning media). Usmaedi *et al* (2020) stated that, in analyzing the needs of the *development tool,* it collects data related to what is needed during the process of developing a product (learning media). The results of the device requirements analysis consist of *software, hardware,* and asset sources to be used in developing a product. The *software* used in developing AR-based mobile applications is a) *Windows Microsoft is* used to manage, combine, and store data, b) *figma,* a web-based application that is used to design the *interface* or prototype of the application project to be developed, c) *unity,* a *game engine* that is used to create and operate the games that have been made, d) *blender* which is used to edit 3D AR assets used in applications to be developed, e) *vuforia* used to help make AR applications on android or *mobile phones* (iOS android) so that they can be distributed to various types of mobile phones and f) *Visual Studio Code is used* to make it easier to edit the programming language used to develop AR-based mobile applications, in this case, the programming language used is c *sharp* (C#). Furthermore, the *hardware* used in developing AR-based mobile applications is a) 25GB of storage which is used as storage to install the required *software,* as well as storage for AR-based mobile application projects, b) 12GB of RAM serves to store programs or data. which is accessed when the computer is active, c) Nvidia GeForce Mx130 2GB serves to help translate or convert digital signals from the computer into a graphical display on the monitor layer, d) Intel Core i5 8250U is used to process all activities carried out by computers, e) laptops are used to develop AR-based mobile applications and f) *smartphones* are used to operate AR-based mobile applications that have been made. Finally, the source of assets consists of a) *Freepik,* a site that provides stock of 3D animated designs, vector designs, or photos (images) that will be integrated into AR-based mobile applications being developed, b) *Sketchfab,* a platform that empowers new ways to create 3D models and makes it easy for anyone to publish and use 3D modeled content or topics in formats such as web, AR and VR, and c) youtube used to search for videos that are input into the AR application that is made.

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Design Stage

This stage focuses on the planning process for making the program including the first mapping of learning materials, this learning material mapping activity is carried out to adapt it to the material contained at the junior high school level, this activity is carried out to determine the limits of the material that is input into the developed AR-based mobile application. Format determination aims to facilitate the preparation or development of AR-based mobile applications. The media format includes audio, image, video, and 3D object sizes that will be inserted into the developed media. Third, the design of the course of the AR-based mobile application development stage, the design of the course of AR media development is an illustration of how the process of developing a software application will be made. The design of the development path consists of several activities, namely 1) problem identification, 2) literature study, 3) application development design, and 4) application development.

The fourth is the design of the running of AR-based mobile applications, the design of running AR media is an activity carried out at the design stage with the aim of 1) knowing how the story or AR application will be developed, 2) not being confused in determining the scheme or concept of the AR application to be made. This activity was assisted by the C sharp programming language and visual studio code to make it happen. The design of the course of the AR media, namely in the form of a flowchart, can be seen in Figure 4.

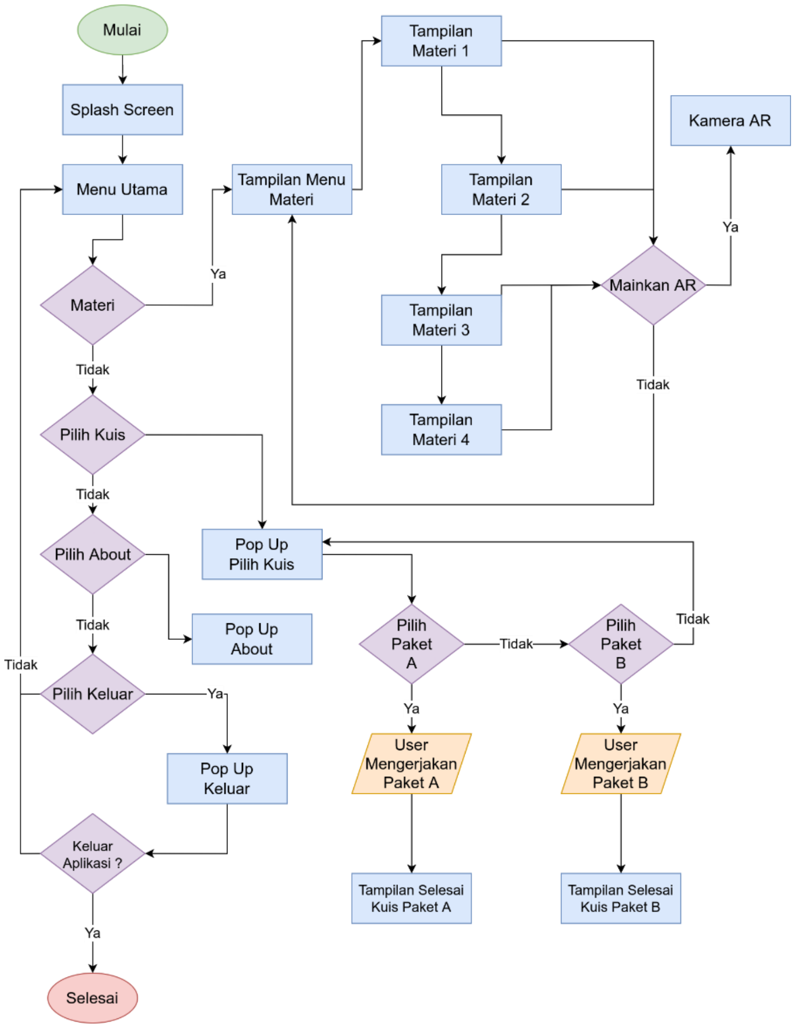

Figure 3. *Flowchart* of AR media

Finally, determining the features and display design of AR media, determining the features and display design of AR media is assisted by the *Figma application*. *Figma is* in charge of designing the *interface* that appears when *the* user plays the developed AR media. In addition, features are needed so that users can easily access the menus provided on AR media, for example, the learning materials menu,

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quizzes, enrichment menus, or menus about applications. Next is the display design AR made according to the age of class VII students, including colors, icons, fonts, buttons, and symbols to be used.

Coding Stage

Coding is the activity of translating designs that have been made previously into software (Dermawan & Hartini, 2017). The coding process into software is assisted by C *Sharp* as the programming language and *Visual Studio Code* as the programming language *software.* The result of coding the C *Sharp language* is a *script.* The *script* is a language that translates every command and compiles code in an integrative series of processes so that a medias travel pattern can emerge dynamically when accessed. The results of the C *sharp* coding script and *visual studio code* consist of 1) *PopUpMateri.cs* to set an animation to appear from bottom to top, 2) *ProblemScript. cs* to arrange the answers to each question, 3) *PapanSkor.cs* to give quiz scores on the scoreboard, 4) *ObjectControl.cs* to adjust the appearance of 3D *Objects* on AR media, 5) *Name3D. cs* to set the description of the name of the 3D *object* that appears, 6) *Hyperlink.cs* to give a function to the button when clicked to open the given *link*, 7) *DialogGroup.cs* to set the animation for the appearance of a *pop-up* dialog like a *pop up make* sure it comes out, 8) *BoxNomorSoal.cs* to set the number of questions in the quiz so that the *user* can pass the questions according to what the *user wants*, 9) *BankSoalNew.cs* to set the course of the questions on the quiz, 10) *animation_button.cs* to set the animation when the button is clicked and set the sound when the button is clicked and finally 11) *canvas_transisi.cs* to set the animation and the path of movement between *scenes* or pages. Furthermore, at the coding stage, there is a trial or testing. Testing is carried out to find out errors that occur in each part that has been made, if there is a problem in each part that is made, amendments (corrections) will be carried out. The test results at the coding stage are used for temporary correction of each part of the AR media so that errors do not occur *when* the media is being tested at the *testing stage* can be seen in Tabel 5.

Tabel 5. Media test results at the coding stage

No	Test Cases	Test Scenarios	Expected results	Test results	
				accordance	**Accordance**
1.	*Splash screen* page	View the splash screen when logged in to AR media	No long loading	V	
2.	Main menu page	Doing a test on the main menu buttons	Each button leads according to the intended page	V	
3.	Basic competency pages, indicators and learning objectives	Scrolling on this page and checking suitability between KD, indicators, and learning objectives	The scroll button is not disturbed (liked) and KD, indicators and learning objectives are appropriate	V	
4.	Page menu materials	Do a test on the menu buttons	Each button leads according to the intended page		V
5.	Page about the application	Seeing the suitability of the menu content and testing the button returns to the main menu	The appropriate menu content and buttons can be used and returned to the main menu	V	
6.	The page about the enrichment quiz	See the suitability of quiz content and enrichment as well as the correct or wrong response button on the quiz	Appropriate content and response buttons according to wrong or correct answers	V	
7.	AR markers	Move/scan the AR camera to the object maker	When moving the AR camera on the marker, the appropriate virtual object appears	V	

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Testing Stage

Product Eligibility

In the testing phase, content validation tests were carried out by material and media experts to determine the feasibility of the AR media that had been developed. The validation involved material experts, media experts, and science teachers. Material expert validation is carried out with the aim that the material used is good and suiTabel for use by students (Prihandini et al ., 2021). Material expert validation was carried out by media experts and science teachers, totaling 10 validators. The data obtained from the material expert validation in the form of a feasibility percentage can be seen in Tabel 6.

Tabel 6. Material expert validation test results

No	Aspect	V score for each aspect	Information
1	Content Quality	0.795	Currently
2	Alignment of Learning Objectives	0.844	High
3	Feedback and Adaptation	0.833	High
4	motivation	0.791	Currently
5	Content Eligibility Components	0.822	High
6	Language Components	0.878	High
7	Serving Components	0.878	High

Based on Tabel 6, the results of the validation of material experts on average (Vaverage) are 0.834 in the high category and are suiTabel for use. This is in line with the research of Buchori et al. (2017) and Ahied et al. (2020) that learning media must be tested before using the material aspects of the media being developed. Furthermore, based on the results of the material expert validation it can be seen that the linguistic component aspects and the presentation component aspects get the highest results, while the motivation component aspects and content quality aspects get moderate results. This is because the linguistic component aspects and component aspects of language presentation used are clear, simple, and concise, and the presentation of AR media is following the development of science and technology and makes it easier for students to understand the material.

The aspects of the motivational component and the aspect of content quality received moderate scores because in these two aspects, many revisions were carried out including adjusting AR media so that it could motivate students, as well as displaying real learning in the AR media that was developed, while the content quality aspect needed to be improved as some material lacked detail, lots of writing errors and typos. The results of the validator's suggestions and comments include 1) improving the material for abiotic components and biotic components, 2) removing excessive material such as neutralism and predation which are explained 2 times, 3) adding material that causes reduced diversity of living things, 4) changing the video explanation of animated material to video real in everyday life, and 5) adding materials related to efforts to preserve living things along with explanatory videos.

Media expert validation is carried out with the aim that the resulting media is suiTabel for use (Prihandini et al ., 2021) and in accordance with predetermined indicators. Media expert validation was carried out by media experts and science teachers, totaling 10 validators. Media expert validation results can be seen in Tabel 7.

Tabel 7. Media expert validation results

No	Aspect	V score for each aspect	Information
1	Appearance Design	0837	High
2	User interaction	0.819	High
3	Accessibility	0811	High
4	Content Quality and Purpose	0.933	High
5	Instructional	0.889	High
6	Technical Quality	0811	High

Media expert validation results in an average (V average) of 0.850 with a high and feasible category. In addition, this AR media has gone through a very rigorous process and evaluation, as well as through small improvements to each unit to produce good AR media. Revisions or improvements to

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the media include 1) distinguishing indicators and learning objectives at each meeting, 2) changing the location of the AR button under the direct explanation of the material, 3) giving a title when 3D objects appear, and providing a background for 3D 4) adding more diverse objects, 5) adding a skip button for quiz questions, 6) adding a menu to the instructions for use regarding download markers, 7) replacing markers with better ones. Based on the validation results of media experts, it can be seen that the aspects of content quality and objectives obtained the highest validation results, while the aspects of technical quality and accessibility obtained the lowest results. This is due to the quality of the content and the purpose of AR media referring to the VII grade Middle School Science curriculum regarding the interaction of living things and their environment. In addition, the core of the discussion used refers to the depth, and breadth of the material in the student and teacher's books and then adjusted to credible books or references, then presentation of material, audio displays, pictures, and videos regularly to obtain very high validation results. Meanwhile, in terms of technical quality and accessibility, media expert validation scores are obtained, among other aspects. type so that it affects the results of the last validation skip button or skip on quizzes and enrichment which also affects the validation value of the media expert. This is in line with Asyhari & Silvia (2016) that learning media must meet eligibility and be educative. Pratama et a.l (2020) and Yovan and Kholiq (2022) that learning AR media is a feasible and valid medium for use in learning science. Dewi et al. (2017) and Ahied et al. (2020) emphasized that the feasibility and validity test of a media needs to be done so that it can be used and can be used to improve students' cognitive.

Student Response

The results of the trial of student responses after using AR media for the interaction of living things and their environment which was carried out at SMP Negeri 3 Jombang with a total of 30 students can be seen in Tabel 8.

Tabel 8. Student response test results

No	aspect	Value Each Aspect	Information
1	Ease of Use	3,233	Well
2	Time efficiency	3,333	very good
3	Benefits of Use	3,267	very good
4	As independent learning	3,275	very good
5	Attractiveness	3,483	very good

The results of the analysis as a whole, the responses of students related to the use of AR media for the interaction of living things and their environment obtained an average result of 3,311 which is in the very good category. Based on the results of the student response questionnaire analysis, it can be seen that the attractiveness aspect gets the highest percentage, this is because AR media is considered new and different from the media that has been used in schools. While the aspect of ease of use obtained the lowest percentage, this indicates that some students have not been able to operate AR media on their smartphones, for example, errors when using AR media such as loading long and the appearance of AR which takes a long time.

Media that has been developed besides being declared valid also gets a very good response from students. Habibati et al. (2019) stated that the existence of AR media can easily understand the subject matter delivered by the teacher. The ease of using AR media is because in AR media it provides interesting, real and, memorable learning nuances, this is what can trigger students to easily understand the material of the interaction of living things. Ismail et al. (2019) emphasized that AR media enables students to be more active in learning activities as well as a source of independent learning because it contains features that make it easier for students. This is in accordance with Thondrike's behavior theory that AR media can provide stimulus and response to students. The interest of students in learning about the interaction of living things and their environment through AR media is a form of response that essentially forms a good association between impressions and behavior, besides that the excellent response of students after using AR media is the result of a good learning process. fun and memorable and accepTabel to students (Amsari & Mudjiran, 2018). Utami et al. (2021) stated that the concept of AR media can create an interesting and fun learning atmosphere, besides that the appearance of 3D objects creates a more real learning atmosphere and can attract the focus of students, as well as give a

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good impression, this is also confirmed by Romadhon et al. (2017) that AR media can visualize material in 3D as attractive as possible. Pratama et al. (2020) confirmed that AR media can increase interest, and AR is very effective and efficient when applied to learning (Affriyenni et al ., 2020).

Science Learning Motivation

Data on learning motivation of students at SMP Negeri 3 Jombang in conventional science learning (control) and science learning classes using AR-based mobile applications (experiments) taken before (pretest) and after (post-test) during the implementation of learning in class. Based on the results obtained in the control class before the implementation of science learning, namely that there was not a student who was motivated to learn science in the "very good" category, 6 students who had the "good" category motivation, 20 students had the motivation to study science in the "enough" category, and 6 students have the motivation to learn science in the "less" category. The control class's science learning motivation increased after conventional science learning, namely 2 students had the "very good" category of science learning motivation, 15 students had the "good" category of science learning motivation, 12 students had the "good" category of science learning motivation, and the category of "less" as many as 3 students. After exploring science learning more deeply in the control class, learning motivation has increased. Based on the number of students who experienced an increase, the motivation to learn science in the "very good" category increased 6.25%, the "good" category increased 27.62%, the "enough" category decreased 25% and the "less" category decreased 9.37 %.

The results obtained in the experimental class before the implementation of science learning were 1 student with motivation to learn science in the "very good" category students, 7 students in the "good" category, 20 students in the "less" category and 4 students in the "less" category. the results of science learning motivation in the experimental class increased after learning with an AR-based mobile application that had been developed, namely as many as 8 students in the "very good" category, 21 students in the "good" category and 3 students in the "enough" category. Based on students who experienced an increase, the motivation to learn science in the "very good" category increased 22%, the good category increased 3.12% and the "sufficient" category decreased 3.12%. The comparison of the results of students' motivation to learn science before and after the implementation of science learning in the control class and the experimental class can be seen in Figure 4.

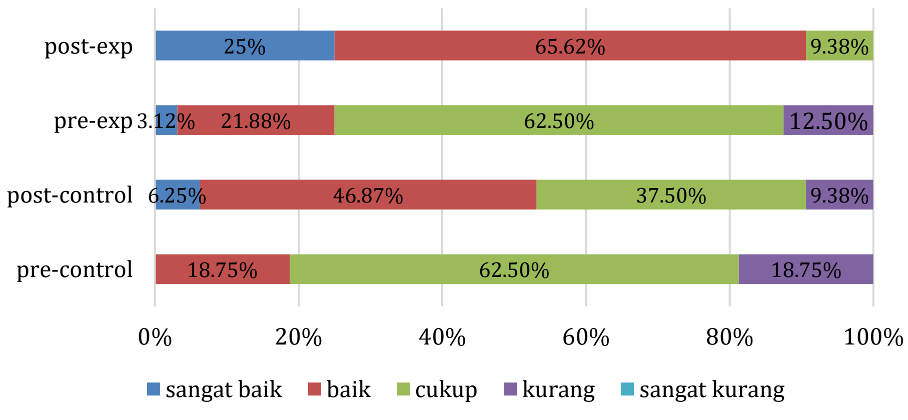

Figure 4. Comparison of learning motivation before and after the treatment of the control class and the experimental class

Based on Figure 4, students' motivation to learn science increases by using an AR-based mobile application. This is supported by the facts in the field that students are interested in learning using learning media, besides that the motivation of students are motivated when the science learning process uses learning, therefore AR-based mobile application media is feasible to develop and apply in learning (Pratama et al., 2020). If seen from the results of the questionnaire distributed to students, the results of the AR-based mobile application for science learning show an increase in motivation from before to after learning. So it can be concluded that learning science using AR-based mobile applications is feasible to increase learning motivation.

The effect of AR-based mobile application media on students' motivation to learn science can be seen through descriptive data and the results of hypothesis testing. The descriptive data shows an average increase in science motivation before and after learning in the experimental class. Based on the results of testing the hypothesis, it can be concluded that the use of multimedia science learning with AR-based mobile applications affects student motivation (Areni et al., 2018). Rahman et al. (2017) confirmed that media learning can generate motivation, interest, and influence the psychology of students in the learning process. This is in line with Wulandari et al. (2020) state that, learning can reduce verbalism and make students better understand the learning material so they can increase student learning motivation, as well as generate enthusiasm for learning, where direct interaction between students and learning resources (Elvina & Dewi, 2020). This goes hand in hand with the research of Syawaludin et al. (2019) that AR media is capable of providing positive changes to the learning process. Fakhrudin and Kuswidyanarko (2020) emphasized that AR media has benefits in various fields, for example in the field of education AR media can present more interesting material. This is in line with Jean Piaget's constructivist learning theory, Sugrah (2019) and Oktavianti et al. (2018) determine that knowledge (cognitive) students are the result of the initial knowledge that has been owned by new knowledge gained. AR media is capable of presenting 3D objects interesting so that students get new experiences, new experiences It has a relationship with the initial knowledge of students so it is very important and beneficial for students. This is also in accordance with Thondrike's behavioral learning theory that AR media can provide a good stimulus to students so that students give a good response in the form of motivation and feelings enjoy using AR-based mobile applications (Amsari & Mudjiran, 2018).

Science Learning Outcomes

This study also calculates the increase in science learning outcomes of students between the control class and the experimental class. The learning outcomes measured in this study are cognitive. The measurement calculates whether there are differences in learning using AR-based mobile applications (experimental class) and classes without being given treatment before and after learning science. The data that has been obtained is then tested using the *paired t-test* to determine the increase in science learning outcomes in the control class and the experimental class. Before testing the data, a normality test (*Shapiro-wilk*) was carried out to find out whether the data was normally or not normally distributed. The basis for making a decision is to find out if the data is normally distributed or not, if the sig value is <0.05, then the data is not normally distributed and if the sig value is > 0.05, then the data is normally distributed (Ahmad et al., 2020). The results of the data normality test can be seen in Tabel 9.

Tabel 9. Results of normality test for control and experimental class data

	Class	Shapiro-Wilk		
		Statistics	df	Sig.
Science Learning Outcomes	pretest control	,970	32	,490
	posttest control	.965	32	.367
	pretest experiment	,935	32	052
	posttest experiment	.983	32	,889

**. This is a lower bound of the true significance.*
a. Lilliefors Significance Correction

Based on Tabel 9, it is known that the data obtained is normally distributed because the sig value > 0.05, then the data is normally distributed. Once it is known that the data are normally distributed, then a paired t-test will be carried out. The basis for making decisions to find out the differences in the control class (conventional learning) and the experimental class using AR-based mobile applications is that if the sig (2-tailed) value is <0.05, there is a difference in the average science learning outcomes of students for the experimental class pretest/control and posttest experimental/control class and if the sig value (2-tailed) > 0.05 then there is no difference in the average science learning outcomes of students for the experimental/control class pretest and the experimental/control class posttest. The results of the *paired t-test are in* Tabel 10.

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Tabel 10. Test results paired samples T-test

		Paired Differences					t	Df	Sig. (2-tailed)
		Means	std. Deviation	std. Error Means	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	pretest_contr - posttest_contr	-7,000	7,357	1,301	-9,653	-4,347	-5,382	31	.000
Pair 2	pretest_exs - posttest_exp	-17.125	7,308	1,292	-19,760	-14,490	-13,256	31	.000

Tabel 10 shows that the sig (2-tailed) value is 0.000 <0.05, so it is concluded that there are significant differences in the pretest and posttest in the control class (conventional) and the experimental class using AR-based mobile applications. Furthermore, this is also proven by the difference in the average pretest and posttest of the control class and the experiment where in the pretest of the control class the average value was 61.125 and after applying conventional learning in the control class the posttest value of the control class increased by 7.045 so that the average value became 68.17 while the average pretest score for the experimental class was 66 and after implementing AR-based mobile applications in science learning the posttest class average score increased significantly by 17.125 so that the average value became 83.125. A summary of the average pretest and posttest scores obtained from the control class and the experimental class is presented in Figure 5.

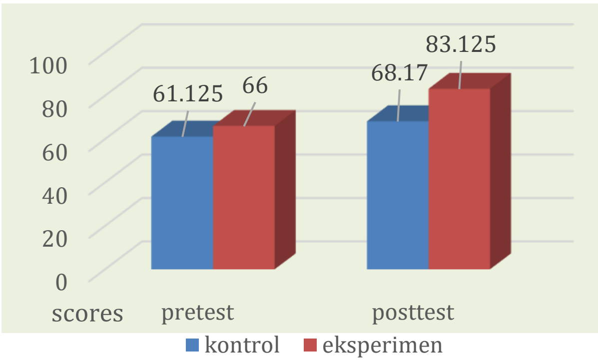

Figure 5. The Average Score of Learning Outcomes

Students' science learning outcomes increase when using AR-based mobile applications, along with increased motivation and science learning outcomes. The games contained in the product can make students more enthusiastic, provide meaning, and provide motivation to participate in learning rather than learning in a controlled class. According to Rismayanti (2021) 1) AR media is capable of giving meaning to students and providing new experiences. 2) The *reconstruction* meaningfully facilitates learning experiences with the help of learning media, the relationship is that AR media can facilitate students in understanding the material interaction of living things and their environment. 3) *Production* which means the existence and expression of appreciation of the concept of learning based on cognitivism and constructivism. The relationship with AR media is that AR media can provide reciprocity in the form of appreciation of students' cognition and constructivism so that the knowledge of students increases.

Maintenance Stage

The final journey of developing AR media material on the interaction of living things and their environment is *maintenance. Maintenance* is carrying out operations such as maintenance, adjustments, or changes to the actual situation (Puspita *et al*., 2019). Melinda *et al.* (2021) stated that the *maintenance stage* is a process of repeating development starting from analysis to *maintenance*, but this is done to change existing AR media, not to create new media. The *maintenance phase* is carried out after the trial phase is complete. The final journey in developing AR media regarding the interaction of living creatures and their environment is *maintenance. Maintenance* is carrying out operations such as maintenance, adjustments, or changes to the actual situation (Puspita *et al* ., 2019). Melinda *et al.* (2021) stated that the *maintenance* stage is a development process starting from analysis to *maintenance*, however, this is done to change existing AR media, not to create new media. *The maintenance* phase is carried out after the testing phase is completed. Results from the maintenance stage Tabel 11.

Tabel 11. Results of the maintenance phase

No	Constraint	Maintenance	Before	After
1.	Long loading	Application size	141MB	109 MB
2.	Long loading	The camera beam does not immediately produce 3D animation	Markers are not clear 	Markers are clarified by changing the marker pattern 
3.	Long loading	Scrolling through the material is a little disturbed	Errors in code in programming languages	Improve programming code

The advantages of AR media material on the interaction of living things are 1) can present 3D animation that seems real or real-time , 2) there are quizzes and enrichment that can help students practice abilities and knowledge especially on the interaction of living things and their environment, 3) There are various features that can make it easier for students to understand the material the interaction of living things and their environment, 4) there is audio on AR media which can increase attractiveness and be different from other AR media, and 5) easy used and understood. In addition to having the advantages of AR media interaction material living things and their environment have drawbacks, namely 1) their size which is too large, so it needs at least 2 GB of RAM to operate, besides that this has an impact on the performance of AR media on smartphones or cellphones. 2) The smartphone camera must be normal and in good condition with size 11 up to 16 MP medium category, otherwise, it will interfere with the appearance of 3D objects on AR media. This is what should be considered in using AR media.

CONCLUSION

The results of development and research show that 1) AR-based mobile applications can be used anytime and anywhere. The product is equipped with 3-dimensional and 2-dimensional animation facilities, images, games, enrichment, and animated videos, as well as application features that are very interesting and suiTabel for implementation in learning, 2) AR-based mobile applications are suiTabel for use with high material and media suitability and student response in very good criteria, finally 3) the use of applications can increase students' motivation and science learning outcomes on the interaction of living things and the environment. AR-based mobile applications can be developed even better in further research on the same or different material to measure students' abilities in the cognitive, psychomotor, and social domains.

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