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Development *Augmented Reality* Based *Flashcards* on Molecular Geometry Material for Increasing Interest in Learning High School Student

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Abstract: Application with integration technology required for describing material geometry molecular nature abstract become more concrete. Study This aims to develop learning media flashcards based on augmented reality material geometry molecules and knowing quality product which was developed. Study This adapts from the ADDIE (analyze, design, development, implementation, and evaluation) model. Quality products will validate and rated by one expert material, one media expert, four reviewers (chemistry teacher), and responded by ten high school students. Instruments used for study form sheet evaluation quality product use the Likert scale and sheets respond students use the Guttman scale. Rating result quality products by expert material obtain a percentage of 96% in the Very Good category, from earned media expert percentage of 92.8% in the Very Good category, for reviewer chemistry teacher get a percentage of 95.4% in the Very Good category, and get response positive from student with percentage 98%. Based on the results evaluation can concluded that developed products _ are worthy using as alternative learning media for the material geometry molecule for increased interest Study high school students.

Keywords: *Augmented Reality; Flashcards;* Interest in Learning Student; Molecular Geometry

Introduction

Technology education has become the main pillar for realizing success in the learning process in the era of the Industrial Revolution 4.0 (Ghufron, 2018). Educational Technology Works To facilitate learning starting from design, development, use, management, and evaluation results in learning to be appropriate with developments over time (Surani, 2019). Educational Technology helps objective learning achieved in a way that is effective and efficient (Agustian & Salsabila, 2021). Using technology education in the learning process can increase understanding of the material (Fatwa, 2020), enthusiasm Study (Lestari, 2018), and interest study (Endra et al., 2020). Educational Technology also helps teachers more creative and innovative in preparing the learning process (Haleem et al., 2022). Therefore regarding the importance of technology education in the learning process, the teacher must skilled in utilizing technology education (Purnasari & Sadewo, 2020). According to Constitution Number 14 of 2005, teachers are required to control technology education to increase competence the pedagogy is purposeful learning achieved optimally (Sitompul, 2022). However, the situation on the ground shows only about 46% of teachers are skilled in using technology education (Hung, 2016).

Teacher skills in control technology eduation can improved through training and mentoring to use technology in the learning process (Ceha et al., 2016). Teachers are expected to capable of developing various learning media following developments over time (Habibah et al., 2020). Instructional media is a device that becomes the intermediary stimulus, thoughts, attention, and interestsstudent capable push the

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emergence of the learning process in student (Shalikhah, 2017). Instructional media is required in the learning process because own excess from the material taught by the teacher becomes more interesting (Karo-Karo & Rohani, 2018) and improve result study (Trisiana, 2020). However, that became a problem until now from minimal learning media innovation for support understanding an adaptive concept in the era of industrial revolution 4.0 (Oke & Fernandes, 2020). Therefore, more learning media is needed innovative (Munawarah et al., 2021).

Creative and innovative learning media is key to a learning process becoming more interesting (Budiyono, 2020). An innovative type of learning media, one of them is *Flashcards* (Maryanto & Wulanata, 2018). *Flashcards* are a learning medium practically loaded with text, images, and symbols shaped cards small for help direct the visuals of the image to students (Utami et al., 2021). *Flashcards* are naturally interactive and can be equipped with pictures or quizzes (Fidiyanti, 2020). *Flashcards* are also available and presented with integration technology through code certain for visualizing abstract objects digitally (Utami et al., 2021). Use *flashcards* capable of increasing interest Study (Maronta et al., 2023), training independence (Rahman et al., 2021), and enthusiastic student in follow learning (Listiyani et al., 2021). Based on research conducted by Utami et al. (2021), conveys that *flashcards* have superiority in increasing effectiveness, flexibility, and clarity problems. However, in deep activity learning many teachers still utilize learning media as is so that the result is not enough maximum (Kusumawati & Mariono, 2019). With so, necessary exists innovation in the use of learning media with the integration of more modern technology so the learning process more interesting (Harta et al., 2021).

Augmented Reality (AR) is a technology interactive that presents real-world integration with a 3D virtual world (Permana et al., 2018). Principle Work *augmented reality* detects object real markers for processing and matches them to the stored data, then virtual objects are displayed through the *rendering* process so that virtual objects appear on a monitor that looks like they merge with real objects (Kurniawan, 2017). *Augmented reality* technology can used as a learning medium to be more informative and interactive (Gufron *et al.*, 2019). Additionally, *augmented reality* is also capable of increasing interest in Study (Kartini, 2022), understanding draft (Ansori & Setyasto, 2021), experiencing fun learning (Apriani et al., 2021). *Augmented reality* can help activity learning become more interactive and efficient (Kamiana, 2019). Therefore, augmented reality is very suitable for explaining lots of material containing draft abstracts (Qorimah et al., 2022).

Chemistry is field of study thai contains abstract concepts (I. N. T. A. Putra et al., 2021). Knowledge chemistry discusses structure, nature, arrangement, and change material along with the energy that accompanies it (Adawiyah et al., 2021). In essence, knowledge chemistry is divided into two parts, namely chemistry as process and product (Priliyanti et al., 2021). Chemistry also has characteristics that require knowledge power visual abstraction and reasoning are more difficult to understand by students (Ampile et al., 2022). In terms of This is a problem in understanding draft chemistry caused by the incompetence of students in connecting levels of representation symbolic, macroscopic, and submicroscopic (Ristiyani & Bahriah, 2016). Therefore, deep learning knowledge chemistry students must understand draft chemistry completely (Hubbi et al., 2017). However, some students still feel difficulty in learning chemistry Because they need logic, mathematics, and language to understand material chemistry (Zakiyah, 2018).

One of the materials considered chemistry difficult is geometry molecule *(Fujiwara* et al., 2020). Understanding geometry molecule covers material theory hybridization electron, theory *Valence Shell Electron Pair Repulsion* (VSEPR) and electron domain, until prediction form the molecule (Hurrahman et al., 2022). Most of the students Still consider material geometry molecules difficult to study Because their Power imagination is tall so that often happens misconception (Anggriawan & Budiasih, 2017). According to the results of research conducted by Nisa and Dwiningsih (2021), stated that interest Study studying material geometry molecules is Still classified as low. The low-interest Study studying material geometry molecules is caused Because material nature is abstract and complex (Hidayah & Destari, 2019). Abstract nature material geometry molecules can visualize with augmented reality for more concrete which makes it easier for students to study it (Nazar et al., 2020). Convenience students in learning material geometry molecules are very influential to interest Study students (Harefa et al., 2020).

Interest in learning is a fundamental aspect of the chemistry learning process (Anggorowati, 2020). Interest learning is influenced by interest studying the material, so that students' are motivated to learn (Putri & Rifai, 2019). Apart from that, interest in learning also influences students' concentration on the material (Mustofa et al., 2023). Interest in learning also influences other aspects such as attitudes and behavior (Charli et al., 2019), and students' learning outcomes (Kartika et al., 2019). The emergence of students interest in learning material is influenced by internal factors, for example their initial ability to understand the material (Harefa et al., 2020). Apart from this, there are external factors

consisting of the school environment and society(Marlina, 2021). Therefore, strategies are needed to increase students interest in learning (Nurida et al., 2022). Efforts that need to be made include utilizing more interactive learning media (Harefa et al., 2020). Therefore, learning media is needed that can foster interest in learning, so that learning objectives are achieved optimally (Nurfadhillah et al., 2021).

Based on the problem description above, this research aims to develop learning media in the form of Flashcards with Augmented Reality technology on molecular geometry material to increase high school student's interest in learning. The hope is that this learning media innovation will be able to increase understanding of concepts and foster students' interest in learning, especially molecular geometry material. Apart from that, this media can be a reference for innovative learning media for a teacher to convey molecular geometry material which is classified as abstract more concretely to help students learn the material so that the learning process feels more interesting.

Method

The type of research carried out is R&D (Research and Development). R&D is a research method that produces new products and tests the effectiveness of these products (Sugiyono, 2016). The research conducted refers to the ADDIE instructional design model. The ADDIE model has five main stages, namely, (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) (Branch,2009).

The analysis stage aims to analyze need, which includes analysis of the needs of teachers, students, facts, concepts, learning material procedures, and learning objectives. This stage aims to collect the data needed to develop flashcard learning media based on augmented reality on molecular geometry.

The design stage is the stage of designing the product that will be developed and includes five stages, based on the research conducted (Mustika et al., 2017). The first stage is to determine the media according to the characteristics of the students to achieve the competencies that have been determined, the second stage is to determine the media format, namely flashcard and supporting applications, the third stage, is making an initial design of the product to be developed, and fifth stage, creating quality test instrumens and product implementations.

The development stage as the core stage includes making a product that is adapted to the initial design and validating the product. The product that has been developed is then assessed by one material expert, one media expert, and four reviewers to get input and suggestions. The instruments used in the research were product validation sheets and product quality assessment sheets.

The implementation stage is carried out to test the revised product. Implementation of limited field tests on ten Class X high school students in Yogyakarta City. The results of limited trials serve to refine and determine student responses to the product being developed. Then evaluate the product to determine the suitability of the product as a medium in the learning process.

Data analysis techniques resulting from product quality assessments from media experts, material experts, and reviewers are in the form of qualitative assesssments which will be converted into quantitative assessments or scors based on a Likert scale (Sugiyono, 2012) which can be seen in Table 1.

Table 1. Scoring rules score

Information	Score
SB (Very Good)	5
B (Good)	4
C (Fair)	3
K (Less)	2
SK (Very Poor)	1

Next, from the assessment data, the average score is calculated using Formula 1.

$$\bar{X} = \frac{\sum x}{n} \quad (1)$$

Keterangan:

$\bar{X}$ = Average Score

ΣX = Total score of each assessor

N = Number of assessor

The overall average score is then converted into a qualitative value according to the ideal assessment category which can be seen in Table 2.

Table 2. Ideal assessment criteria

Score range	Category
Xi + 1,8 SBi < X	Very Good
Xi + 0,6 SBi < X ≤ Xi + 1,8 SBi	Good
Xi – 0,6 SBi < X ≤ Xi + 0,6 SBi	Fair
Xi – 1,8 SBi < X ≤ Xi – 0,6 SBi	Less
X ≤ Xi – 1,80 SBi	Very Poor

The data analysis technique resulting from student responses is carried out by changing qualitative data into quantitative data (scores) using the Guttman scale which can be seen in Table 3.

Table 3. Guttman scale administration rules

Information	Score
Yes	1
No	0

The data that has been processed in the form of a score is then calculated for the overall ideal percentage of the product using Formula 2.

$$\text{Ideal Percentage} = \left(\frac{\text{Achieved scor}}{\text{Ideal maximum score}}\right) \times 100\% \quad (2)$$

Result and Discussion

The product developed in this research is learning media in the form of augmented reality-based flashcards on molecular geometry material. Flashcards were chosen because of their practical nature, containing images, text, and symbols to direct students' visuals related to the images. Apart from that, flashcards can also be presented with technology integration through certain codes so that they can visualize abstract objects digitally. Based on research by Sukma et al. (2021), the use of augmented reality technology media can help foster students' interest in learning, train independent learning, and clarify material that looks abstract. This research adapts the ADDIE model with stages:

The **analyze** stage includes needs analysis by observing and interviewing four teachers and students about problems in chemistry learning at SMA Negeri 2 Kudus, SMA Negeri 1 Banguntapan, and MA Muhammadiyah 1 Yogyakarta. Based on the results of the interview, information was obtained that molecular geometry material is a difficult material because it contains three levels of representation and requires higher imagination. Most teachers still use learning media in the form of conventional printed modules, PowerPoint, and existing learning videos that do not visualize the three levels of chemical representation. Meanwhile, analysis of concepts, facts, principles, and learning procedures is carried out by identifying core competencies, basic competencies, Competency Achievement Indicators, and the main material of molecular geometry which is used basic concept for the content of the product being developed.

At the **Design** stage, there are five stages including media selection, design selection, reference collection, initial design creation, and instrument creation (Ani & Lazulva, 2020). The selection of media developed is adjusted to the results of the needs analysis. The media chosen in this research is flashcards based on augmented reality. Reference sources were collected using literature studies from university chemistry books, class X high school chemistry books, and journals related to chemical molecular geometry. The initial design of learning media was created with the help of software including CorelDraw, Blender, Vuforia, Unity, and Google Drive. CorelDraw is used to create initial designs because of its easy and flexible ability to create flashcard display designs according to needs. Blender is used to create 3D designs of molecular geometry. Vuforia is used to import flashcard display designs from CorelDraw so that they can be read by Unity. Unity is used as a place to combine previously created components including flashcard displays, 3D designs, and UI designs to become an Augmented Reality application. Meanwhile, Google Drive is used to store flashcard displays so that they can be used by anyone, anytime and anywhere without needing a flashcard hardfile. At this stage, an initial product design is produced which will be developed at the next stage.

At the **Development** stage, media creation begins with creating a flashcard display design as media that will be integrated with Augmented Reality technology. There are seven flashcards consisting of Linear, Trigonal Planar, Bent, Tetrahedral, Trigonal Pyramidal, Trigonal pyramidal, and Octahedral molecular geometry cards with a size of 9 cm x 6 cm. The flashcard display consists of one side of the front display which contains brief information regarding the name of the molecular geometry. The results of the flashcard design can be seen in **Figure 1.**

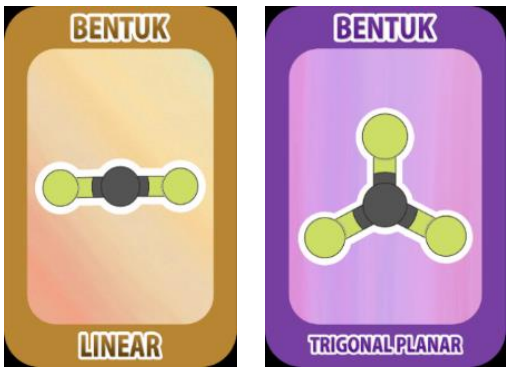

Figure 1. *Flashcard design*

The front display design of the flashcard functios as a target image that will be exported into Vuforia for licensing so that the target image functions properly. The target image functions as a tracker to display 3D images when directed by the device camera. Next, the target image is exported to the Unity application. After that, a 3D design for the molecule was created according to the flashcard display design using the Blender application. The choice of Blender to create 3D visuals is seen from the modeling and animation aspects(Mongilala et al., 2019). After the 3D object is created, it is saved in the form of a .blend extension. The 3D design is then exported into the Unity application

and placed on top of the target image according to the molecular geometry. The process of exporting 3D visuals to the target image can be seen in **Figure 2.**

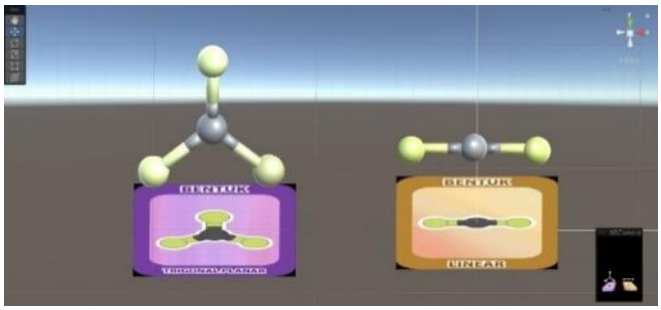

Figure 2. Process exporting 3D visuals to a target image

Next, the process of creating an application display design or UI (User Interface) design. UI design is a visual display of the product that connects the system with the user, serving as the main point of user interaction. The UI design was created using Corel Draw and a combination of tools in Unity, then the design was implemented in Unity software by creating a new empty scene. Next, the prepared UI design model will be integrated into the scene.

The final stage after the application has been created is to compile the application with the .apk extension so that it can then be run on an Android device. The final product produced is an augmented reality application with the name "ARGOM". The layout, type, and size of letters, selection of logos, icons, and background designs are designed to be more attractive so that they can foster students' interest in learning. The ARGOM application has a splash screen display and a main menu. The splash screen and main menu consists of an AR camera button, materials, quizzes, and instructions for use, about the compiler, and an application exit button in the ARGOM application can be seen in Figure 3.

Figure 3. Splashscreen and menu display

Camera AR menu is a working menu for *scan the flashcard* so can displays automatic 3D visualization with the animation. Camera AR menu consists from 2 bottoms namely molecule info and buttons return. AR camera menu display directed at each *flashcard* will displays 3D visuals are appropriate with geometry different molecules. As example *scan* marker on geometry Linear and Trigonal Planar molecules as in Figures 4.

Figure 4. Display animation and info corner

Submicroscopic level on this *flashcard* No only is displayed in two dimensions. However, with integration technology *augmented reality* on the ARGOM application can visualize geometry molecule in 3D shape of geometry $BeCl_2$, BF_3, H_2O, CH_4, PCl_5, and SF_6 molecules. Combination can help student visualize geometry molecule more attractive and visible in a way real so that can increase interest learn it. This fact in accordance with study Liono et al,. (2021) which states that use combined teaching materials with technology *augmented reality* role in help student visualize 3D shapes for material nature abstract, so makes it easier student in learn material, learning process more interesting, and improving interest study.

Furthermore, there is a material menu that displays submatter geometry molecules. In the material menu, there is a discussion form the geometry molecules based on PEB, PEI, angle ties, and pictures of the molecule so that students can Study in a way without must opensource other. Material menu display can see in **Figure 5.**

Figure 5. Material menu display

The quiz menu consists of three quiz menus, working to serve evaluation learning submitter geometry molecule. Quiz menu uses the linked link to Quizizz so teachers can evaluate the results of learning students through questions that have been provided in the application. In the quiz menu display, one evaluation consisting of ten question choice double and connected with the Quizizz page. The quiz menu display can see in **Figure 6.**

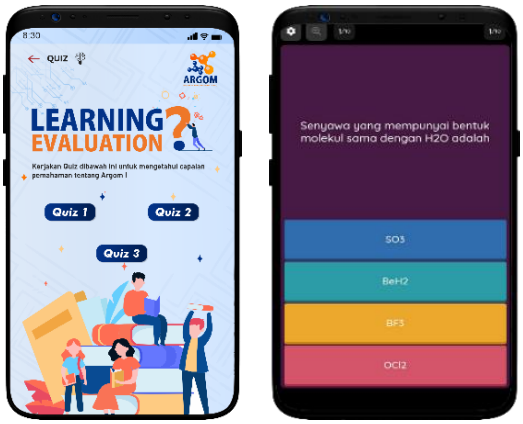

Figure 6. Quiz menu display

Instructions menu containing description method use from available button in applications and methods use AR camera accompanied the *flashcard* download link provided connected with storage on *Google Drive*. Display instructions menu can see in **Figure 7.**

Figure 7. About menu display

In this menu, link *drives* work for makes it easier for students who haven't own *hardfile flashcards* so you can print Alone the flashcard. Appearance *of Google Drive* containing *flashcard softfile* can see in **Figure 8.**

Figure 8. Display *flashcard* files in *Google Drive*

Finally, there is an *About* menu which contains about profile *developer* application. The *About* menu can be displayed in **Figure 9.**

Figure 9. *About* menu display

After the development application is finished, the next step Then make packaging for *flashcards,* display packaging can see in **Figure 10.**

Figure 10. Packaging design *flashcards*

Packaging *flashcards* designed interesting with a goal for students interested in using media in the learning process. Packaging is made with objective the main thing is that *the flashcard* remains protected quality and clarity of the picture. This is very important Because the picture is the main marker that will be read in the system *Augmented Reality* so fixed 3D view Can displayed, with there by product will still awake the quality.

Stage furthermore is compiled instrument evaluation for quality product and response student. Products produced then assessed for quality by expert material, media experts, and *reviewers*. Aspect assessment used includes Content, Illustrations, *User Friendly*, Quality System, Flashcard Design, *Augmented Reality,* and Interest in Learning. Rating results quality products and responses students can see in Table 4.

Table 4. Research results quality product and response student

Evaluation	Assessment Aspects	∑ Score	∑Ideal Maximum Score	Ideal Percentage	Category
Material expert	Material Contents	19	20	95	Very good
	Language	19	20	90	Very good
	Interest to learn	10	10	100	Very good
Media expert	Illustration	19	20	95	Very good
	Quality System	15	15	100	Very good
	User Friendly	13	15	86.6	Very good
	Appearance Design (UI)	9	10	90	Very good
	Augmented Reality	9	10	90	Very good
Reviewers	Material Contents	78	80	97.5	Very good
(Chemistry	Language	78	80	97.5	Very good
teacher)	Illustration	77	80	96.25	Very good
	Quality System	58	60	96.6	Very good
	User Friendly	55	60	91.6	Very good
	Design (UI)	94	100	94	Very good
	Augmented Reality	36	40	90	Very good
	Interest to learn	40	40	100	Very good
Student	Material Contents	19	20	95	Very good
	Language	20	20	100	Very good
	3D Visuals	19	20	95	Very good
	ARGOM App	20	20	95	Very good
	Interest to learn	20	20	100	Very good

Based on Table 4, the results of the assessment of augmented reality-based flashcard products on geometry material to increase interest in learning for class X SMA students were obtained. The assessment by material experts obtained an ideal percentage of 96% in the Very Good category. Therefore, the product developed is suitable for use as a learning medium to increase students' interest in learning. This is by research conducted by Maharani et al., (2022), which states that the use of augmented reality-based flashcards by learning objectives can increase students' understanding of the material and interest in learning. The assessment results from media experts obtained an ideal percentage of 92.8% in the Very Good category so the product developed is suitable for use as learning media in the classroom. This is in line with research conducted by Supriono & Rozi (2018), which states that the quality of augmented reality-based learning media and supporting applications in the very good category can be used as learning media in the classroom. The results of product quality assessment by reviewers obtained an ideal percentage of 95.4% in the Very Good category. The media developed can make the material taught more concrete. These results are by research conducted by Utami et al. (2021), which states that the development of augmented reality-based flashcard learning media can make abstract material concrete. The assessment of teachers as users has a very important role in assessing the suitability of the media that has been developed with student characteristics. The learning process using augmented reality-based flashcard media can also increase students' understanding of concepts and interest in learning because it helps teachers in conveying learning material so that it can attract students' attention to better understand the material.

Next, at the implementation stage, the product that has been developed is implemented on a limited basis to ten SMA class X MIPA students. Student responses were carried out by filling out a Google form questionnaire using the Guttman scale, which consists of five assessment aspects and ten indicators, each containing five positive and negative statements. The results of student responses show a product ideal percentage of 98% in the Very Good category. The positive response

given by students shows that students are very interested in the product that has been developed so that it is easier for students to understand the molecular geometry material presented with the integration of Augmented Reality technology. This is supported by the results of research conducted by Maharani et al., (2022) which obtained results of 94.04% in the Very Good category, so that the resulting product is suitable and effective for use as a learning medium that can increase students' interest in learning.

As an instructional media, flashcard products based on augmented reality with molecular geometry material certainly have advantages and disadvantages. One of these advantages is that the use of augmented reality-based flashcards can make the learning process fun. It is easier for students to understand the material so they can improve their understanding of the concept (Fitriani et al., 2021). Apart from that, the use of augmented reality-based flashcards can also increase students' interest in learning in the learning process (Setiawan et al., 2022).

One of the weaknesses in using flashcard products containing augmented reality submaterial molecular geometry as a learning medium is the limited number of compounds and molecular geometries developed. This media does not yet display all the molecular geometries of various compounds because only a few forms are available for sampling, so students can only observe the molecular geometry in Visual 3D of the compounds provided in the application.

Conclusion

Based on the results of research that has been carried out, the flashcard product that has been developed has user-friendly characteristics and has multiple representations in its supporting applications. The results of the quality assessment of the products developed according to material experts received an ideal percentage of 96% in the Very Good category, material experts 92.8% in the Very Good category, and reviewers 95.4% in the Very Good category. Furthermore, based on the results of the response, students received a positive response with an ideal percentage of 98%. Thus, it can be concluded that the development of augmented reality-based flashcards on molecular geometry material is suitable for use as alternative chemistry learning media to increase high school student's interest in learning.

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Author Contributions
Reny Alfina Rahmawati contributes to conceptualizing the research idea, developing products, analyzing data, and writing articles. Agus Kamaludin, a supervisor in research activities to article writing, reviewed, and edited.

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The authors declare that there is no conflict of interest regarding the publication of this paper.

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