Contextual Science Learning using Smartphone Audio Sensor Application (Phyphox) on Restitution Coefficient Measurement

(Received 12 December 2021; Revised 26 November 2022; Accepted 30 November 2022)

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Abstract

The cognitive development of elementary school student are at a concrete operational stage, so that prospective elementary school teachers must have knowledge and experience in managing contextual and meaningful learning. The obstacle to the implementation of practicum while online learning during the Covid-19 pandemic, so an alternative method is needed to carried out in a home experiment. In the daily life of the students, collision events are often encountered. Many kinds of playing ball (i.e., tennis balls, basketball, and ping-pong ball) are examples of collision events. This research aims are to develop material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application. The Research and Development (R and D) through ADDIE design has been applied to achieve the objectives of this research. The stages of this research were carried out through the stages of Analysis, Design, Development, Implementation and Evaluation. This research has produced a material content elastic collision experiments of contextual science learning for prospective science teachers through using the Phyphox application. The average percentage of material expert validation results related to indicator of content quality, content compliance and content language is 93.33%. The experimental results show that the coefficient of restitution of the small basketball on the ceramic floor is 0.848; for tennis balls 0.716 and for ping-pong balls is 0.836. The collision for the three types of the balls with the floor are classified as partially elastic collisions. It can be concluded that the material content elastic collision experiments of contextual science learning for prospective science teachers using the Phyphox application are in very feasible criteria and valid to be implemented in basic science concept lectures. The implication of this research indicates that smartphone-based experiments using phyphox application motivate and makes various science experiments more accessible with simple methods to analyze experiment data. Home experiment activity using Phyphox application is recommended to help students to describe and determine the type of collision, determine the energy lost during a collision and the coefficient of restitution, draw a graph of the relationship between height and time in a contextual and meaningful way of science learning activity.

Keywords: Contextual Science Learning, Smartphone, Science Home Experiment, Phyphox

INTRODUCTION

The cognitive development of elementary school age children (7-11 years) is in the concrete operational stage. At this stage the child still has difficulty in abstract thinking. Students will better understand concepts through logical and systematic manipulation of symbols related to concrete objects (Carbonneau et al., 2013). This implies that prospective elementary school teacher students must have the knowledge and experience to be able to provide an alternative experiment or real practice for elementary school students. The contextual approach to learning is recognized as a reasonable approach and is expected to improve students' science learning outcomes (Neftyan et al., 2018; Fu et al., 2019; El Islami, Nuangchalerm, & Sjaifuddin 2018; Nuangchalerm & El Islami 2018; Parmin, Nuangchalerm, & El Islami, 2019; Parmin et al 2020; El Islami & Nuangchalerm, 2020; Rowan, Correnti & Miller, 2002; Maphoso & Mahlo, 2015; Antony & Elangkumaran, 2020; Ott et al., 2018; Mnguni et al, 2020). The purpose of contextual learning is to teach students to understand concepts related to real life. Contextual learning can be applied as an effort to improve students' higher-order thinking skills and self-efficacy (Haryanto & Arty, 2019; Simamora & Saragih, 2019).

Based on the experience of accompanying the Basic Science Physics Concept course, the practicum has not been carried out using smartphones. In online learning, smartphones have become a mandatory tool in online learning from elementary school to university levels. The obstacle to the implementation of practicum while online during the Covid-19 pandemic is that students or students cannot practice in the laboratory directly, so easy learning practicum facilities are needed by utilizing available materials and easy to find in the students' daily environment.

The existence of smartphones in online learning is the main capital in carrying out physics practicum at home. In addition to the negative effects of smartphones in everyday school life, smartphones can also be used to improve physics learning in schools. Utilization of applications that can be accepted from the smartphone capabilities of students can facilitate student interest and motivation in learning physics. Smartphones can be used as a tool to obtain information, to document experiments and to conduct experiments independently (Kuhn & Vogt, 2013; Ballester et al., 2014).

The smartphone's built-in acceleration sensor can be used to assist quantitative experiments in a school or university environment, such as free fall experiments, radial acceleration, and exploration of everyday contexts. Smartphone-based experiments can motivate students as it allows them to explore physics with their own tools. The Phyphox application makes various physics experiments more accessible with simple methods and trains students to be able to analyze the results of the data displayed (Fox et al., 2020; Howard & Meier, 2021; Hwang, & Purba, 2021). Some physics experiments that can be done with the phyphox application include mechanical experiments, such as free fall, centripetal acceleration, lift speed, collision, and the period of a pendulum or spring; sound experiments, such as measuring the frequency and resonance of sound; pressure experiments as well as electricity and magnetism. (Vogt & Kuhn, 2014; Carroll & Lincoln, 2020; Staacks, et al., 2018).

Smartphones have become a versatile measuring device in the field of science (physics) (Oprea & Miron, 2014; Hochberg et al., 2018). Various physics experiments, both experiments in the laboratory or the phenomena of daily activities carried out can be observed using applications on smartphones. The use of smartphone applications has several advantages, including replacing measuring instruments in expensive laboratories, providing opportunities for students to make observations and physical measurements in students' daily activities. Students can observe natural phenomena directly anytime and anywhere using their respective smartphones, then analyze the experimental results and the accuracy of observations by understanding the concepts they have. Students can relate the results of observations and their effects in everyday life (Smith & Worsfold, 2014; González et al., 2015).

Collision is one of the materials contained in science (Physics) lessons. Collision is an event where two objects meet. In the daily life of students or students, collision events are often encountered. Bekel ball games, baseball using tennis balls, basketball are examples of collision events. In the collision experiment in determining the coefficient of restitution, generally the observation of motion parameters is still done manually. The high position of the reflection of the ball or object under study relies on the accuracy of the observer which is then measured using a ruler. The process of course depends on the accuracy of the measuring instrument and the subjectivity of the observer. Observers are also required to observe the height of several reflections in a limited time so that they are prone to errors in observations. One way to minimize these errors is to use technology to replace the role of the observer in the form of an audio sensor smartphone Phyphox application. This research aims are to develop material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application.

METHOD

Research and Development (R and D) The ADDIE (Analysis, Design, Development, Implementation and Evaluation) design is applied to achieve the objectives of this research. The ADDIE design (Cheung, 2016) used in this research (See Figure 1). Each stage of the ADDIE design is then developed into several technical research work steps (Saeidnia et al., 2022).

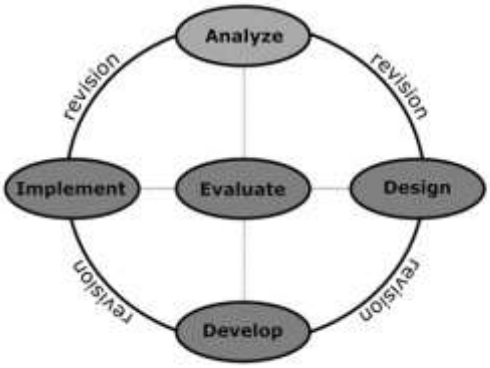

Figure 1. The ADDIE designs

The research data was taken in the even semester 2022 natural science basic concepts course. The research subjects were 45 prospective elementary school teacher students taking Basic Science courses. The analysis step of developing material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application is the needs assessment process, identifying problems (needs) and performing task analysis. The design stage is to design a material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application. Product design is still conceptual and underlies the subsequent development process. The development step contains activities to realize the design of material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application. At the design stage, a conceptual framework for the material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application. At the development stage, the conceptual framework is realized into a product that is ready to be implemented. Implementation step is applying the design of material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application that has been developed in real situations in the classroom or in locations that allow testing the results of the development. After that, then an initial evaluation was carried out to provide feedback on the product. This evaluation stage is also carried out extensively at each stage of ADDIE design. The evaluation results are used to provide feedback to product. Revisions are made if and only in accordance with the results of the evaluation or unmet needs of the material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application.

The data collection instrument used a questionnaire to determine the feasibility of the material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application. Feasibility studies through expert assessments consisting of five lecturers who are in accordance with the research field, they are from the science education and elementary school education study program to validate material content.

The data analysis technique used descriptive analysis to assess the characteristics of the data. The data were analyzed descriptively in the form of developmental data and questionnaire responses. This research uses a Likert scale questionnaire with 5 scales, namely very feasible, feasible, quite feasible, less feasible, and not feasible, can be seen in Table 1.

Table 1. Assessment with a Likert Scale

Statement	Score
very feasible	5
feasible	4
fairly feasible	3
less feasible	2
not feasible	1

The results of the questionnaire response scores were analyzed by calculating the average answer based on the score of each answer from the respondents which was calculated using the formula:

$$P = \frac{n}{N} x100\%$$

Where:

P: Percentage of responses

n: The total score obtained

N: Total criteria score

The results obtained are then presented according to Table 2 below:

Table 2. The Feasibility Score and Criteria

Percentage (%)	Criteria
81 - 100	very feasible
61 -80	feasible
41- 60	fairly feasible
21 - 40	less feasible
0 - 20	not feasible

RESULTS AND DISCUSSION

Based on the analysis stage, the development of material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application resulted in a needs assessment are: (1) the material characteristics of the material content elastic collision; (2)

Specifications of experiments of contextual science learning for prospective science teachers using the Phyphox application; (3) identify problems (needs) for material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application.

The design stage is to design a material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application. The proposed elastic collision material content design is based on the needs analysis in this study, namely verify alternative elastic collision experiments, determine the energy lost during collision, the coefficient of restitution, and draw a graph of the relationship between height and time using the Phyphox application.

The development stage has realized the product design of content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application. Experiments have been carried out to determine the coefficient of restitution of objects using a smartphone audio sensor application sensor (phyphox). To get good results, make sure the room is quiet and protected from sounds other than collisions that can be recorded by the smartphone microphone.

The experimental steps are through observe and analyze the falling motion of three types of balls, namely rubber basketball, tennis balls, and ping pong balls using the Phyphox application. The tools and materials used in the experiment were smartphones, the Phyphox application, three types of balls (tennis balls, ping pong balls, small basketballs), and ruler meters.

Figure 2. Elastic Collision Experiment Tools and Materials

The experimental procedure is as follows:

1. Open the phyphox application on the smartphone, select the Mechanics (in) elastic collision section

Figure 3. Display of the Phyphox Application on a smartphone

2. Arrange tools like pictures and press the Play button on the phyphox application
3. The initial height of the experiment was 50 cm and 100 cm which were measured using a meter
4. Ball-shaped objects (small basketball, tennis balls and ping pong balls) are dropped from an initial height of about 1 meter

Figure 4. Series of Elastic Collision Experiment Tools and Materials

5. Repeat data collection 3-5 times
6. Experiment using the Phyphox application, in (elastic collision) on a smartphone

The data from the analysis is calculated using the equation for the partially elastic collision to obtain the value of the coefficient of restitution.

After experimenting with three types of balls, the following results were obtained and displayed in Table 3. The experiment result in Table 3 shows the percentage of energy reduced when there is a collision between the rubber basketball and the floor, from experiments 1, 2, and 3, the restitution coefficient value is e=0.8414, indicating that the collision that occurred was a partially elastic collision.

Table 4 shows the percentage of energy reduced when there is a collision between a tennis ball and the floor, from experiments 1, 2, and 3 the restitution coefficient value e = 0.7169 indicates that the collision that occurs is a partially elastic collision. Table 5 shows the percentage of energy reduced when there is a collision between the ping pong ball and the floor, from experiments 1, 2, and 3 the restitution coefficient value e = 0.8365 indicates that the collision that occurs is a partially elastic collision.

The graph of the relationship between the height of the ball and time based on Tables 1, 2, and 3 is shown in Figure 5.

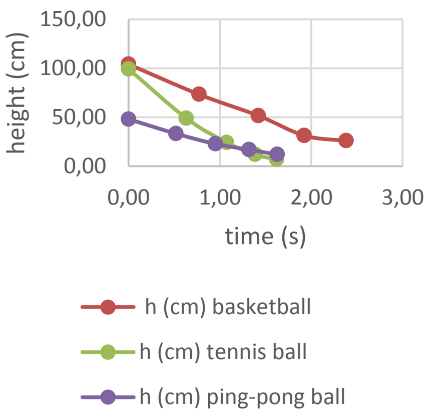

Figure 5. Graph of ball position (h) versus time (t)

Table 3. Small Basketball Experiment Data

No	Experiment 1			Experiment 2			Experiment 3			Average h (cm)	Average t (s)	$e = \sqrt{\frac{h_2}{h_1}}$
	h (cm)	t (s)	E (%)	h (cm)	t (s)	E (%)	h (cm)	t (s)	E (%)			
1	104.74	0	100	103.79	0	100	103.46	0	100	104.00	0.00	0.8389
2	73.12	0.77	69.8	71.72	0.77	69.1	74.74	0.78	68.8	73.19	0.77	0.8391
3	51.04	0.65	48.7	49.57	0.64	37.9	54.00	0.66	53.5	51.54	1.42	0.7782
4	35.63	0.54	38.4	27.18	0.47	29.3	30.83	0.50	43.7	31.21	1.92	0.9095
5	28.06	0.48	26.6	20.98	0.41	24.6	28.42	0.48	30.9	25.82	2.38	0
		average retained	71,9			71.3			72.1			0.8414

Table 4. Tennis Ball Experiment Data

No	Experiment 1			Experiment 2			Experiment 3			Average h (cm)	Average t (s)	$e = \sqrt{\frac{h_2}{h_1}}$
	h (cm)	t (s)	E (%)	h (cm)	t (s)	E (%)	h (cm)	t (s)	E (%)			
1	99.59	0	100	99.73	0	100	98.36	0	100	99.23	0.00	0.7022
2	49.24	0.63	49.4	48.96	0.63	49.21	48.57	0.63	49.4	48.92	0.63	0.7022
3	24.35	0.45	25.9	24.04	0.44	20.9	23.99	0.44	26.1	24.13	1.08	0.7021
4	12.77	0.32	14.0	10.25	0.29	-	12.66	0.32	-	11.89	1.39	0.7611
5	6.89	0.24	7.6	-	-	-	-	-	-	6.89	1.62	0
		average retained	52.6									0.7169

Table 5. Ping-Pong Ball Experiment Data

No	Experiment 1			Experiment 2			Experiment 3			Average h (cm)	Average t (s)	$e = \sqrt{\frac{h_2}{h_1}}$
	h (cm)	t (s)	E (%)	h (cm)	t (s)	E (%)	h (cm)	t (s)	E (%)			
1	48.00	0	100	47.62	0	100	48.36	0	100	47.99	0.00	0.832
2	34.16	0.53	71.2	32.54	0.43	68.3	32.93	0.51	68.1	33.21	0.52	0.832
3	24.31	0.38	50.6	22.23	0.37	50.3	22.43	0.43	47.5	22.75	0.95	0.845
4	17.28	0.32	35.9	16.35	0.31	36.3	15.63	0.36	30.5	16.85	1.32	0.837
5	12.28	0.27	26.8	11.83	0.27	28.1	10.4	0.29	20.1	11.82	1.63	0
		average retained	72			72			67			0.8365

The coefficient of restitution is calculated using the equation $e = \sqrt{\frac{h_2}{h_1}}$. Based on the experimental results, the coefficient of restitution for rubber basketball on ceramic floors is 0.848; for tennis balls 0.716 and for ping-pong balls obtained a value of 0.836. Some sports practices in schools and colleges that are done indoors are practiced on the floor using a ball. The height of the ball bounce from the floor surface is a parameter that determines the durability of the floor for indoor sports facilities. The sports flooring used must meet standards for parameters such as absorption of a certain amount of impact energy, floor surface, adequate ball bounce, specific surface friction and adequate resistance to rolling loads. In FEM digital modeling, the basketball used meets FIBA (International Basketball Federation) standards, the coefficient of restitution (COR) is empirically 0.815 and digitally 0.800 (Noskowiak, 2016).

The value of the coefficient of restitution for collisions usually lies between 0 and 1, depending on the event the collision is experiencing, the collision is not elastic at all, or is completely or partially elastic (Cross, 2021). Based on the coefficient of restitution for 3 types of balls (basketball, tennis ball and ping pong ball) with respect to the floor, all three are classified as partially elastic collisions. In a partially elastic collision, the law of conservation of kinetic energy does not apply because there is a change in kinetic energy before and after the collision, so that in a partially elastic collision only the law of conservation of momentum applies and the coefficient of restitution for a partially elastic collision has a value between zero and one (0<1) (Giancoli, 2001).

This experiment works by using a smartphone microphone to detect the sound produced by the ball hitting a ceramic floor surface. By analyzing the time interval between the sound produced by the collision and considering that, after each collision, the ball will retain the same percentage of kinetic energy that the ball had before bouncing, the Phyphox application determines the height from which the ball falls and the kinetic energy of the ball after each collision as percentage of the ball's initial kinetic energy.

The experiment was done by letting the balls fall from a certain height so that they could get some balls to hit the floor. The smartphone's microphone detects the sound produced by the ball's collision with the floor and records the time it takes between successive collisions.

Based on Table 1, Table 2, and Table 3 after the ball hit the floor there was a reduction in the percentage of energy. In the event of a basketball collision with the floor and a ping pong ball with the floor the average percentage of energy retained after the collision is in the range of 71.9% and 72%, respectively, while the tennis ball with the floor is 52.6%. So that it can be seen in table 2, in experiments 2 and 3, the height data only detected 2 reflections. In the three types of balls used in the experiment, the motion of the ball bouncing following the motion of the parabola. There are many forces acting on a real ball, namely the gravitational force (FG), the drag due to air resistance (FD), the Magnus force due to the rotation of the ball (FM), and the buoyant force (FB). Broadly speaking, to analyze the motion of a ball, Newton's second law must be used including all the forces present:

$$\sum \mathbf{F} = m\mathbf{a},$$

$$\mathbf{F}_{\mathrm{G}} + \mathbf{F}_{\mathrm{D}} + \mathbf{F}_{\mathrm{M}} + \mathbf{F}_{\mathrm{B}} = m\mathbf{a} = m\frac{d\mathbf{v}}{dt} = m\frac{d}{d}$$

where m is the mass of the ball. In the formula, a, v, r represents the acceleration, velocity, and position of the ball with respect to time.

When the ball hits the surface, the surface will repel and vibrate, so does the ball; creates sound and heat and the ball loses kinetic energy. In addition, the collision can give the ball a slight rotation, converting some of the translational kinetic energy into rotational kinetic energy. The energy lost is usually characterized (indirectly) by the coefficient of resilience (denoted e):

$$e = -\frac{v_{\mathrm{f}} - u_{\mathrm{f}}}{v_{\mathrm{i}} - u_{\mathrm{i}}},$$

where v_f and vi are the final and initial velocities of the ball, while u_f and u_i are the final and initial velocities when it strikes the surface respectively. In the special case where the ball strikes an immovable surface, the coefficient of resilience becomes simpler, namely:

$$e = -\frac{v_{\mathrm{f}}}{v_{\mathrm{i}}}$$

For a ball that falls on the floor, the coefficient of resilience will range between 0 (not elastic, total loss of energy) and 1 (completely elastic, no energy loss). A resilience coefficient value below 0 or above 1 is theoretically possible but would indicate that the ball penetrates the surface (e<0) or the surface is not "slack" when the ball strikes it (e>1), as in the case of the ball landing on a filled spring platform. Besides being able to be used in determining the coefficient of restitution, the Phyphox application has several advantages for presenting physics science concepts to students, for example on the concept of kinematics in junior high school (Pierratos et al., 2020).

In this experiment, the calculation of the earth's gravitational acceleration (***g***) was also carried out as a validation of the experimental data with the vertical upward motion equation:

$$h = \frac{1}{2} g \left(\frac{\Delta t}{2}\right)^2$$

$$g = \frac{2h}{\left(\frac{\Delta t}{2}\right)^2}$$

where t= $\frac{\Delta t}{2}$ or the time after the first bounce to the next bounce. Table 4 shows the results of each calculation of the ***g*** value from small basketball, tennis ball and ping-pong ball experiments.

Table 6. The results of the **g** calculation using small basketball, tennis ball and ping-pong ball experiments

Small Basketball			Tennis Ball			Ping-Pong Ball		
h (cm)	t (s)	g	h (cm)	t (s)	g	h (cm)	t (s)	g
73,19	0,77	9,81	48,92	0,63	9,81	33,21	0,52	9,83
51,54	0,65	9,81	24,13	0,44	9,81	22,75	0,43	9,84
31,21	0,50	9,84	11,89	0,31	9,84	16,85	0,37	9,85
25,82	0,46	9,86	6,89	0,24	9,81	11,82	0,31	9,84
Average g		9,83	Average g		9,82	Average g		9,84

Based on the results of the three experiments, the average value of g is 9.83 m/s^2 with the direction towards the center of gravity. According to Müller (2018) at latitude 86.71o and longitude 61.29o above the surface, the arctic ocean has the highest gravitational acceleration of 9.8337 m/s2 in the world. The result of the ***g*** value is in accordance with the theoretical gravitational acceleration that the value of the gravitational acceleration is between 9.8 m/s^2 to 10 m/s^2 (Maryam & Fahrudin, 2020; Bara, 2021).

The implementation stage of material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application that have been developed in real situations in classrooms or locations that allow testing the results of the development carried out. However, the discussion of this article is limited to the results of expert assessment using questionnaires to validate content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application. The results of the feasibility study through five expert assessment of material experts is presented in Table 6.

Table 6. Results of Material Expert Validation

No	Aspect	Percentage Validation Score (%)	Criteria
1	Content Quality	93.33	very Feasible
2	Content Compliance	90.00	Feasible
3	Content Language	96.66	very Feasible

The average percentage of material expert validation results is 93.33%. Based on the results of the validation has reaching a percentage between 81-100 so that it was considered very feasible criteria.

After implementing the material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application, an evaluation is then carried out to provide feedback on the material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application from the notes or suggestions of experts. The lowest percentage of validation scores from material content experts on the content adherence aspect. In this aspect, the material content elastic collision experiments of contextual science learning for prospective teachers using the Phyphox application has material that is broader than the content mandated by the curriculum. This is intended so that the content of learning material is more comprehensive. According to the expert suggestions, material on elastic collision experiments can be summarized and added to a list of terms so that it helps students more easily understand the elastic collision material based on contextual science learning (Serway & Jewett, 2018; Volioti et al., 2022).

Based on the data analysis indicates that smartphone-based experiments using phyphox application facilitate contextual science learning that motivate and makes various science experiments more accessible with simple methods to analyze experiment data. Home experiment activity using Phyphox application is recommended to help students to describe and determine the type of collision, determine the energy lost during a collision and the coefficient of restitution, draw a graph of the relationship between height and time in a contextual and meaningful way of science learning activity.

CONCLUSION

This research has produced a material content elastic collision experiments of contextual science learning for prospective science teachers through using the Phyphox application. The average percentage of material expert validation results related to indicator of content quality, content compliance and content language is 93.33%. The experimental results show that the coefficient of restitution of the small basketball on the ceramic floor is 0.848; for tennis balls 0.716 and for ping-pong balls is 0.836. The collision for the three types of the balls with the floor are classified as partially elastic collisions. It can be concluded that the material content elastic collision experiments of contextual science learning for prospective science teachers using the Phyphox application are in very feasible criteria and valid to be implemented in basic science concept lectures. The implication of this research indicates that smartphone-based experiments using phyphox application motivate and makes various science experiments more accessible with simple methods to analyze experiment data. Home experiment activity using Phyphox application is recommended to help students to describe and determine the type of collision, determine the energy lost during a collision and the coefficient of restitution, draw a graph of the relationship between height and time in a contextual and meaningful way of science learning activity.

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