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A case study of curriculum-based game design for k-12

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Abstract: While it has already been widely established that games can be assimilated into the education mainstream achieving excellent results, the current researches focusing on classroom-based educational game for k-12 are relatively fewer than that on other areas. In this paper, we analyzed the currently existing related educational games for k-12, then attempted to analyze and design a suitable game matching withk-12 class teaching based on syllabus. Finally, we tested this game on corresponding graders with great success. We sincerely hope that these ideas and our experiences can be worthy of the following relevant works.

Keywords: K-12, Educational game, Classroom learning, Game design, Game evaluation

1. Introduction

Currently, in the field of educational games, great progress is being made in programming new games and applying them to the classroom, most of which is built upon cooperation between the educational game industry and schools to create, produce, and apply certain informal games.

On the other hand, Andrew J. Stapleton (2004) found that while the K-12 sector is recognized and understood as a possible market for games, presently it is not considered a key focus within the serious games community.

Furthermore, many difficulties have arisen in integrating these educational or traditional games into the k-12 classroom. For example, in the study of McFarlane (2002), through surveys of the teachers and parents, it was determined that although they believe that games can support the healthy development of logic reasoning, mathematics, coordination and so on, they think the greatest obstacle in the full integration of games into the curriculum is that their contents do not completely match. Meanwhile, the abilities that students may gain from these games may not be helpful when used in formal, traditional education.

As a result, through analysis of current related articles and existing related educational games, it seems that rarely have educators or researchers paid attention to how to integrate games with "formal" class teaching or produced "formal" school-based games to match the syllabus of class teaching, especially, on the aspect of K-12 primary education.

In this paper, after discussing the current situation of educational game, we introduced the whole progress of analyzing, designing, realizing and evaluating a sample of classroom-based educational game for k-12. We sincerely hope that these ideas and our experiences can be worthy of the following relevant works.

2. Analysis of existed related games

As our study shows, the majority of the existing programs lean towards one of two extremes (Prensky, M, 2003).

On one end, it may follow MMOrpg （Massive Multiplayer Online Role Playing Games） format, incorporating many roles, complex rules and stories as well as making the portion of the game non-relevant to educational material, which would bring an extra bundle of information that the

students must learn. This is counterproductive to the goal of making games lighten the cognition load of education.

On the other end, many educators and game-designers are well aware of this flaw, thus leading to the other extreme: monotonous games with no story or point that are loaded with textbook style information, such as quiz games, which seems like normal paper tests except shows on screen and by using music, score, vivid interface and some other forms of game. The whole process is just answer the questions and judge the answers right or wrong. When this is the case, the players quickly lose interest in the game once they play enough to familiarize themselves with the format. Focusing on classroom-based educational game in k-12, we have discovered an interesting phenomenon, which is that the story and point of the game is very often far removed from its educational content and it is a great challenge to the attempt to bring these two ends to meet. Many programs that fail to achieve a unification of the two present the educational portion as question-answer format. For example, in order to strike a monster or advance a step in a dungeon, the player must answer a scholastic question that is entirely non-relevant to the monster or the dungeon. This unnatural forcing together of two completely different worlds of thought is a great downfall for many games and thus, any new program that we design must overcome this flaw by creating a smooth transition or link between the scholastic information and the game-play.

Thus, we conclude that the current classroom-based educational games in K-12 are inadequate and further research is necessary to create programs to overcome these fatal design flaws. Especially, as many educators and researchers have referred to (Squire Kurt, 2006), keeping the balance between "entertainment" and "education" in an educational game is a key point, which we need to specially stress on in the following work.

3. Perry's game: a sample case of curriculum-based educational game for k-12

3.1. Site and sample selections

Before realizing a suitable educational game, we must choose a specific discipline and target audience on which to test our method. Therefore, we created a formal educational game that aimed to meet three targets: one, to be suitable for the K-12 audience; two, to be compatible with classroom teaching; three, to achieve a balance between entertainment and education. Thus, we decided to choose measurement skills from the K-12 curriculum (Alternative Education/Special Education Division, 2008) on which following test-run is based. Reasons as below:

3.1.1. Match up curriculum

Through analysis, we have found that as a cell of discipline, measurement skills are included in the syllabus of 1st to 5th graders and are good representative skills for the K-12 curriculum.

3.1.2. Match up requirements from school

From the feedback of students and teachers, we can see that although the concept of measurement is straight-forward and simple, many children do not possess a comprehensive command of the subject. Thus, we have concluded that a measurement game would be helpful to the students in their cognitive development.

3.1.3. Fill up the lack of satisfied related educational games

Through our research on programs dedicated to improvement of measurement skills, we have found that there are very few of them, and the ones that do exist are in either question answer format, which does little to differentiate them from a textbook, or simulation-type games, which very boring and lose the point of using software rather than an actual ruler and object. These games fail to achieve the goal of entertainment.

3.1.4. Provide useful experience for following relevant game design

Experience tells us that the simpler the concept of discipline, the more difficult it is to create a fun and engaging program for it. As we know, linear measurement skills are very straight forward and simple. Thus, if we can successfully create a fun and engaging program on it, it may provide some useful experiences to future educational games.

3.2. Design of the sample game

3.2.1. Analysis of game's goal

I. Educational goal

Help students in K-12 enhance their understanding and skills on the concept of linear-measurement; make children know how to measure linear objects with standard, non-standard units. Of course, we cannot ignore the value of helping the student to instantaneously realize their errors and faults as this is invaluable towards improvement.

General goal: Measure linear unit: Use a ruler to measure standard/non-standard unit.

a. Standard measurement

To measure item lengths in integers and halves to simulate measuring behaviors by using a standard tool in real world

b. Non-standard measurement:

To simulate measuring behaviors by using a non-standard tool as a reference tool; practice skills of estimating

II. Entertainment goal

To make children feel happy and rewarded through completing tasks; to engage children in the game to break their own record; to make students in K-12 like it and can be engaged in the game to actualize the real "study in the fun". Therefore, they will achieve the educational purpose.

III."Balance" goal

Achieving balance between entertainment and educational goals.

3.2.2. Analysis of the game's target audience

According to the principle of game design based on the original level of different age populations, we must first consider the age, education level and psychology of our target audience (Prayaga, 2005). See Table 1 as below.

Table 1: Target audience compare

Target audience	***Psychology***	***Suggestion for game design***
Children Between 7 and 12 years of age	Active, curious, like to play puzzle games, lack patience, and have a short attention span	Game designer must use vivid images and simple language for presentation and explanation of the disciplines in their fusion into the game.
Children	Active (with	They like analytical puzzle games, role-

betwe en 13 and 18 years of age	purpose), like to think	playing games, so tactic games are more suitable for them. The images should have high resolution.
People above the age of 19	Prefer more complex games with a greater amount of knowledge required	These people pertain to combat games with lots of action and adventures. They love role-playing games with leader or hero-like figures. They love multiplex strategy games.

In this case, we chose primarily 7-12 years old students, thus in our design of the game we must take into consideration the characteristics of the students in this age group. We must focus on the polymerization of the game play with educational content, keeping the game fun and purposefully simplifying the game play.

3.2.3. Choosing an appropriate genre

Before choosing an appropriate genre for the going created game, we carefully analyzed all the candidate game categories, including RPG (Role Playing Game, MMOrpg), ACT (Action Game), FTG (Fighting Game), STG (Shooting Game), SPG (Sport Game), RCG (Race Game), AVG (Adventure Game), SLG (Simulation Game / Strategy Game), PZG (Puzzle Game) and CG (Casual Game) (邹帆,2009).

According to the Piaget's theory of cognitive and affective development (Wadsworth, B. J. ,2004), in children's cognitive structure, the dominant factor is perceptual representation. Children mostly use the thinking in images and the thinking on perception to know the world, so they often like beautiful visuals and dramatic sounds, and often find it difficult to understand complex characters in the story. Thus, MMORPG games are not suitable for them because the missions are complex and so are the relationships between characters. Oppositely, games with simple storylines or games completely absent of storylines such as flash games are more suitable for them.

Therefore, we wish to target measurement skills as the goal of this game. Because measurement skills are simple and exclusive, we hope to create a web-based flash game.

From the perspective of combining game play and knowledge, we hope that this game is compatible for classroom use. Thus, it must first be instructional software. The goals and missions must all be tied with measurements. Second, it must be able to captivate its audiences like a traditional game does. Third, we hope that it can be used as a supplement to the classroom lecture, helping kids more firmly command the knowledge they just learned. Thus, it must adhere to the regular classroom model in most schools, for example, the immersion time must not be longer than the standard 45-minute slot per class.

This game should be a casual game for helping students master the material amid the daily dry and monotonous classroom lectures, reducing students' cognition load. The game should be colorful, vivid, animated, interactive, challenging, pertinent to children's life, and helpful to children's education.

I. Design game's subject

This game should not be limited by a terminating number of levels (high score games), but instead should utilize random looping and be very rewarding. We determined that this game should be a Shooting Game.

II. Design the style of the game's interface

The interface of the game should be simple, colorful, and related to the material inside the game, hopefully matching up to the target audience's interests. See Figure 1 as below.

Figure 1. The interface of game's beginning

3.2.4. Design game's rule

I. Design game's background

- At the beginning of the game, the player will choose the level of difficulty (beginner, intermediate, advanced and hardest) divided to attack different emphases. The storyline is that over a blue sea, and endless and random rain of long objects fall at different speeds. The player must randomly click on an object and perform relevant operations according to the hints. Afterwards, the player must choose the correct length as is written on the clouds. If the answer is correct, the player will receive a corresponding reward. After that, the player will be taken back to the main interface to continue playing the game. If it is wrong, the game will provide the correct answer and once the student has acknowledged this, s/he will be taken back to the main interface to continue the game.
- After a certain number of correct answers, the player will advance to the next level.
- Every level will have different rules, and provide according rewards or incorrect answer screens to the player's progress.

II. Integrate subdivided educational cells into game's rule to achieve the entertainment goal

a. Design of "Objects"

- Normal objects will appear at different locations above the ruler after each answer. The student must use the ruler as a tool to measure the length of the object. Through this, we simulate normal measuring practice.
- Special objects will stop falling when they are clicked and players are required to use the ruler as general reference to estimate the length of the object. This simulates estimation practice.

b. Design of "ruler"

- Ruler with number: the ruler with numbers is a standard ruler with number using the centimeter as the standard unit.
- Ruler without number: the ruler without numbers is a ruler with increments but no corresponding numbers so that the player can only estimate or count the length of the object.

c. Design of "answers"

- When the answer is an integer: it allows the students to practice with full centimeters
- When the answer is a half of a centimeter: it allows players to see that more precise measurements than a whole can be made.

d. Design of locations where chosen object shows up

- When normal objects align themselves with the 0cm mark, it simulates the most common measurement practice in the classroom.
- Normal objects that do not align themselves with the 0cm mark
    a) When normal objects need to be dragged to the 0cm mark to be measured.
    b) Students must align the object, simulating practical measurement.
    c) Objects can only be dragged to an integer other than 0cm mark.
    d) Helps students get a steadier grasp at the concept of measurement (as opposed to only looking at the number that the object ends at).

e. Design of Answer feedback

When the player selects an answer, the game will instantly give feedback, helping students to immediately understand one's own fault and grasp the right answer.

f. integrating "fun" function with "educational" function

Uses multiple interactive properties, vivid animations, enhancing sound effects, and gratifying rewards to engage the player.

4. Evaluation

To test whether our game achieved the original design purpose of allowing students to quickly and easily master the skill of measuring to a proficiency level, we conducted an experiment in which two groups of children were taught measurement concepts by the instructor, to evaluate the effectiveness of the game, to discover the possible flaws of classroom teaching and possibly improve on them.

The experiment: the experiment was pilot-tested in 3th, 4th and 5th grades and results from that pilot were used to improve the experiment.

4.1. Participants

4.1.1. Reasons for choosing 3th, 4th and 5th grades students as sample group

According to previous analysis, we saw that although the k-12 Mathematics Curriculum (Texas Education Agency, 2012) in Texas covers measurement skills in kindergarten through 5th grade, our game targets the sample group that would already have finished the learning of the basics of measurement. In grades kindergarten through 2nd grade, students practice with non-standard units, and in 3rd grade students begin to use a ruler. Therefore, our game targets those students from grades 3 to 5 that have learned the basic concept of measurement and can then deepen their understanding of the topic.

4.1.2. Reason for choosing large number of students from different classes

We selected sixteen different classes from 3th-5th grades (6 third grade classed, 6 fourth grade classes and 4 fifth grade classes) to ensure that the experiment results would truthfully or near-truthfully reflect the actual level of proficiency that the average commands in the area of measurement. This also diminishes the probability that differences in the instructors may sway the results (which is why we divided each classroom into two equal groups for control and experiment with consideration to gender balance).

Therefore, participants in this study included approximately 300 students from 16 4th grade classes at Treasure Forest Elementary School in Houston, TX and 16 4th grade teachers from each class; one observer and one research assistant. See Table 2 as bellow.

Table 2: Arrangement of the participants.

	Sample Population of The Experimental Group	**Sample Population of The Control Group**	**The Total Number of Participants**	**The Number of Classes**
Number	138	145	283	16
Scale	48.8%	51.2%		

4.2. The experiment for evaluation

4.2.1. Purposes of the experiment:

In this phase, we hope to:

- Compare the results of the pretest and post-test of the experimental group to determine that the game at least has educational value.
- Compare post-tests from the control and experimental group (from students with comparable pretest scores) to compare the effectiveness of our game with traditional classroom teaching.

4.2.2. Design of Paper tests

Before executing the experiment, we carefully designed the paper-tests. To ensure the results from pre-test & post-test can be objectively and effectively compared, we created the post-test similar with the pre-test in the number of questions, the varying degrees of difficulty, and the area of coverage. Only the actual questions were completely different.

We created twenty-five questions on the area of measurement according to the curriculum with varying degrees of difficulty, covering all or nearly all aspects of the discipline. ("SKILL1"=can read the integer scale of a standard ruler; "SKILL2"=can put an object to a standard ruler from 0 cm to do the measure activity as in real world; "SKILL3"=can read the scale number of an standard ruler to measure an object; "SKILL4"= can read decimal scales of a standard ruler; "SKILL5"=can measure an object from anywhere of a standard ruler; "SKILL6"=can measure objects by using an standard ruler without number and can estimate objects with a reference). Each question has 1 score with a total of 25 scores. Each question involves one or a few SKILLs respectively, such as question #1 involving SKILL1~SKILL3. In another word, each of the skills would also have accordingly different questions. Thus, each of the skill would involve different numbers of questions and has a different sum. Therefore, to better analyze the study effects of the students', later analysis will not adopt the raw sum of each skill but the percent correct. In addition, to avoid the potential clues from the orderly arrangements of the questions, the questions and according skills are arranged randomly.

Furthermore, we divided those questions into some small groups in detail to make them specially represent the different aspects of measurement skills.

4.2.3. Procedure of treatments

The concrete procedure of the 2 treatments is below:

I. Pre-test: Based on reviewed the correlative concepts of measurement under the same teacher's instruction. All the students had the Pre-test on linear measurement in a limited time (10 min).

II. The control group and the experimental group: to assure comparability, each class was randomly divided into two equivalent groups which have the equal proportion of males and females, one as the control group and the other one as the experimental group.

III. Then the experimental group went to the computer lab to play the game (no instructions were given during their entire playing duration, except helping them access the game online) and the control group stayed in the class room to use normal class practice under teacher's assistance (pencil and paper activity).

IV. Time duration: 40 min.

V. Post- test: 40 minutes later, both groups stopped their respective activities to take the post-test (10 min).

4.3. Gathering data from the experiment

4.3.1. Results of evaluating entertainment goal

This part of data is gathered for validating whether the game achieved the Entertainment purpose.

I. Results From observation

a. A real relaxed gaming time

To get the most effective data and students' authentic feedback, during the whole duration when the experiment group played the game, the researcher and designer were present that did not interact with them very much. Without any interruption, students in this group enjoyed the game and were relaxed.

While they played the game, no matter whether they were shouting, cheering, exhibited exciting, flourishing or playing silently, we could conclude that they were completely engaged in the game.

When forty minutes had elapsed, most of the students in the experimental group wished to continue playing.

b. no instruction, no management, no assistance

At the beginning of their playing, we told them this is game time and they should just enjoy the game and have fun. We suggested that if they met any problem or had any question about how to continue the game, they should carefully observe all the interactions or animations and try to figure it out on them own.

During the whole experiment, seldom of the students needed our assistance. And these finally figured the problem they had after we told them to carefully observe some hints information in the game.

II. Results from questionnaire

a. Feedback from students

Every time when the experiment group was ready to come back to class, we always asked them these questions:

(i) Do you like the game?

All the students from each experiment group loudly said "yes", and urgently shared their feelings and experiences about the game to us.

(ii) Do you think the game is very interesting?

Still a loud answer of "yes". Some said it's very cool.

(iii) Is the game hard? Or easy?

Most of the answers are: it's not hard and not easy, appropriate.

(iv) What have you learned from the game? or did you feel that the game tried to teach you something?

Some said "yes, it teaches me how to measure"; some said "now I know how to measure"; some said "I don't know, because I didn't think about it when I was playing, I just played it". The last statement was the most valuable because it shows that our goal was met.

(v) If possible, do you want to have this game in your class-study?

Everybody said yes. Many of them asked us when they could play it again and asked if they could find it online because they wanted to play it again at home.

b. Feedback from teacher

Prior to experimentation, we asked a class to test the game to ensure that it was free of bugs for the main experiment. The instructor said that she greatly supported these kinds of games entering into the classroom because good ones are so rare and she believed that a game was a great tool for learning as it immediately told the student whether the answer was correct or not and showed the student how to obtain the correct answer. A month later, we received and e-mail from her reflecting that her students loved this program and that their measuring proficiency was greatly improved.

4.3.2. Data from Pre/Post paper tests

This part of the data is gathered for validating whether the game achieved the Educational purpose.

I. The pre-test and post-test data analyze

Before the experiment when both groups had just received the lecture on measurement concepts, the pretest was given to determine their initial mastery of the subject. We required students to complete the test to the best of their abilities in ten minutes. After we received the results, we found that all students had completed all twenty-five questions. After gathered data, we did Independent Samples Test and Paired Samples Test, we can see the means comparison and T-test in Table 3 & Table 4 as below.

Table 3: Means comparison between pre-test & post-test

			TOTAL	SKILL1	SKILL2	SKILL3	SKILL4	SKILL5	SKILL6
Control Group (n=145)	***Mean***	***pre***	11.738	54.23%	69.66%	52.55%	41.23%	31.82%	38.55%
		post	14.372	62.38%	71.24%	60.51%	53.65%	48.32%	52.97%
		post -pre	2.63	8.15%	1.59%	7.95%	12.41%	16.51%	14.41%
	Paired comparison	***t***	-4.835	-3.750	-.743	-3.769	-5.033	-5.615	-5.591
		P	.000	.000	.459	.000	.000	.000	.000
Experimental Group (n=137)	***Mean***	***pre***	12.000	55.93%	70.80%	52.37%	41.77%	32.80%	41.45%
		post	18.942	76.94%	89.57%	78.12%	74.84%	66.57%	72.25%
		post -pre	6.94	21.01%	18.77%	25.75%	33.07%	33.77%	30.80%
	Paired	***t***	-14.014	-9.620	-8.325	-13.479	-14.027	-12.923	-12.825

	comparison	***P***	.000	.000	.000	.000	.000	.000	.000

In Table 3, we can see that before and after treatment control group showed significant difference (t=-4.835, P=.000<.001); however, the SKILL3 showed no significant difference (t=-.743, P=.459>.05); experimental group also showed significant difference (t=-14.014, P=.000<.001), especially every skill level (SKILL1~SKILL6) showed significant difference (p=.000<.001). Thus, we could conclude that the normal classroom-practice and Perry's game both have the educational function. Especially, after using our measurement game the measurement skills of experimental groups were increased a lot which means the game can significantly enhance the player's measurement skills.

Thereby, the measurement game does, indeed, contain educational value. The educational purpose of our basic original design has been met.

Table 4: Means comparison between control group & experimental group

			TOTAL	**SKILL1**	**SKILL2**	**SKILL3**	**SKILL4**	**SKILL5**	**SKILL6**
Pre-Test	***Mean***	***Control***	11.738	54.23%	69.66%	52.55%	41.23%	31.82%	38.55%
		Expri	12.000	55.93%	70.80%	52.37%	41.77%	32.80%	41.45%
		con-ex	0.26	1.70%	1.14%	-0.18%	0.54%	0.99%	2.90%
	T-test	***t***	.282	.467	.311	-.051	.127	.216	.712
		P	.778	.641	.756	.959	.899	.829	.477
Post-Test	***Mean***	***Control***	14.372	62.38%	71.24%	60.51%	53.65%	48.32%	52.97%
		Expri	18.942	76.94%	89.57%	78.12%	74.84%	66.57%	72.25%
		con-ex	4.57	14.56%	18.32%	17.61%	21.20%	18.25%	19.28%
	T-test	***t***	5.267	4.014	5.750	5.112	5.517	4.256	5.068
		P	.000	.000	.000	.000	.000	.000	.000

In Table 4, we can see that before treatments, the pre-test of control group and experimental group showed no significant differences (t=.282, P=.778>.05). Thus, we can draw a conclusion that before treatments, the two group (control group and experimental group) were comparable. Concretely, after analyzing all the t value and P value in every skill levels (SKILL1~SKILL6), we can say that the skills of the control and experimental groups were comparable in all of the modules. In additional, we also observed a very interesting phenomenon. Students scored relatively well when they were allowed to measure from the zero point of the rulers but did significantly poorer when they were not allowed to align the objects with the zero point. This shows that students never really grasped what measurement was.

After treatments, the control group and experimental group showed significant difference (t=5.267, P=.000<.001). we can conclude that our measurement game had more educational value than traditional classroom practice.

We also can get the conclusion via Figure 2.

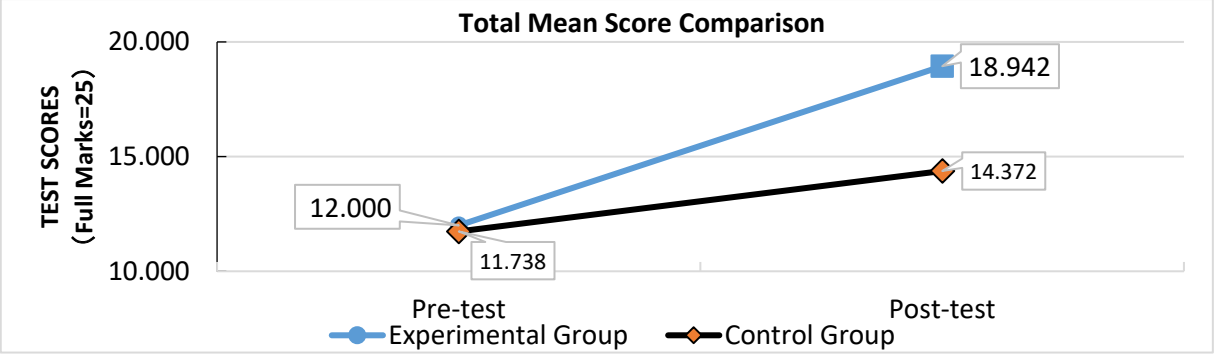

Figure 2. Total Mean Score Comparison

From those tables and figures above, we can obviously discover that the measurement game we designed can subsificantly help student understand the measurement concept and enhance their skills on imeasurement.

5. Conclusion

5.1. Educational function

- Students' scores in the post-test have improved compared to their pre-test scores, establishing the educational qualities of this program.
- The experimental group out-performed the control group on the post-test, establishing that our program is more efficient than traditional classroom doctrine.

Thus, this game is worthy of integration into the common American classroom.

5.2. Entertainment function

Through our previous analyses, we can arrive at a conclusion on the entertainment function. Students love this game; teachers welcome the induction of this game into their classrooms; but best of all, not only does it not add to the load of the teachers, it eases their daily teaching routines.

Above all, through experimentation on students from 3rd to 5th grade and analysis of the numerical results, we discovered that this game can be used as supplementation to the classroom, allowing students to not only master the concepts of measuring, but also practice with application. The results outpace that of traditional classroom teaching. Thus, it achieved the educational purpose.

Through our observations and analysis of the behavioral output of students as they are engaged in the game and the feedback from both students and teachers, we can conclude that students can feel the enjoyment of gaming in this process, achieving the goal of truly learning while having fun- the entertainment purpose.

To sum up, the game we created has achieved our original design purpose. We sincerely hope that these ideas and our experiences can be worthy of the following relevant works.

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