Weatherlings: A New Approach to Student Learning Using Web-Based Mobile Games

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ABSTRACT

Ubiquitous Games (UbiqGames) are browser-based multi-player games played primarily on mobile devices. UbiqGames are designed to be played outside of formal class time and over several days, alongside more traditional instruction in the topics covered in the games. Teachers can use class time to facilitate thoughtful reflection on game strategies and data generated through gameplay. In the UbiqGame Weatherlings, players collect virtual creature cards and "battle" other players in arenas based on real cities, which feature the cities' meteorological data from the recent past. Success in the game requires players to consider climate conditions and do short-term forecasting from this real weather data. In this pilot study, 20 Singaporean 10 and 11 year-olds played Weatherlings using mobile devices over four days, playing primarily outside formal class time. Survey and interview data, combined with server logs, demonstrate positive outcomes for students including strong appeal and high engagement, increased interest in weather, and self-reported improvement in weather prediction skills. Outcomes suggest opportunities for additional research around UbiqGames to probe this new model for game-centered learning.

Categories and Subject Descriptors

K.8 [**Personal Computing**]: Games
K.3.1 [**Computer Uses in Education**]: Collaborative Learning

Keywords

Education, educational technology, games, mobile, video games, ubiquitous, weather

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1. BACKGROUND

A growing body of research (Prensky, 2001; Gee, 2003; Shaffer, 2006) argues that games can be powerful tools for motivating and engaging players, and for developing useful habits of mind as well as domain-specific content knowledge. Games can also be effective teaching tools from which students can transfer knowledge and experience gained in the game environment to another context (Gee, 2003).

Teachers must motivate their students with various extrinsic or intrinsic factors but one benefit of games as teaching tools is that aside from beating the game or scoring points, the process of playing the game itself is fun (Prensky, 2002). This is due in part to the idea that gameplay is one way to reach a state of flow, the feeling of exhilaration and deep enjoyment (Czikszentmihaly, 1990). Research has also found that the most motivating and engaging games are the ones that have a balance of "hard fun" (Papert, 1996), which challenges the player to actively participate in order to learn and master the activity. As a result of this type of game, players are not only engaged during the time they're playing the game, but they are also motivated to continue to play and engage with the content over time.

Many studies have been done on video games, simulations, and other forms of computer assisted instruction, which have shown encouraging results. Work by Vogel et. al. (2006) analyzed 32 empirical studies and showed reliably across these studies that attitudes toward learning after using computerized simulations or games were better than those of students who were taught using only traditional methods. Baranowski et. al. (2008) examined health-related video games and stories and found that they led to various desirable outcomes such as knowledge increases, attitude shifts, and behavior changes. As well, Baranowski's research suggested that games do indeed help to drive interest in academic topics. These and other meta-analyses (Bayraktar, 2002; Christmann and Badgett, 1999) show that good video games and technology-based activities can indeed help students engage with and build skills related to content.

While potential benefits can come from playing educational games, effectively integrating digital game-based learning into

formal education can be challenging. Given already limited instructional time, adding games to the curriculum can be difficult. Moreover, teachers often have limited access to hardware. Many educational games also have a long and/or steep learning curve, and can therefore be intimidating, especially to some teachers.

But not all games fit this mold. With growing recognition of their popularity, so-called "casual games" (Juul, 2009) are different from many traditional electronic (educational) games. Casual games are typically played in sporadic bursts, have simple rules, and are designed for a broad audience to enjoy with a small initial investment of time or learning of rules. The casual style of gaming has inspired researchers (e.g., Klopfer, 2008) to develop new generations of educational casual games, designed specifically to provide simple, easily accessible, yet rich experiences for players and teachers alike.

Casual educational games in general, and the Ubiquitous Games developed by Klopfer et al. in particular, take advantage of their format to engage players with content related to their classroom studies. Ubiquitous Games (aka UbiqGames) are web-based, casual games designed to be played primarily on mobile devices, but able to be played on any computer with a web browser. On a practical level, by making the games ubiquitous (able to be played on handheld computers as well as desktops and laptops), researchers hope to break down some of the barriers to adoption (Klopfer, 2008). UbiqGames are meant to be learning games, but are not meant to replace classroom instruction. Instead, by being casual games that can be played in the interstitial times of the day, UbiqGames are meant to enhance existing classroom instruction. Theoretically, there are several learning advantages that come by virtue of UbiqGames' casual play style. First, there is the opportunity that players have for background processing of the material with which they are engaging. Though players will not spend all of their time between game sessions thinking about the material, they will spend some, which increases their time engaged with that material. A related opportunity is the chance to build experience, expertise, and knowledge over time. Rather than playing in one prolonged event, "beating" the game, and disengaging with whatever material they might learn from the game, students playing casual games are invited to engage with material repeatedly over time, which leads to greater opportunity to construct complex knowledge.

Related to, but distinct from this point, is an important design consideration for Ubiquitous Games that sets them apart from many other casual games. In addition to affording casual game play outside of class, UbiqGames explicitly build in reflection tools that a teacher can take advantage of in a more formal setting, i.e. in class. By building tools for reflection on the experiences they have with the material in the games, the designers of UbiqGames hope to take advantage of experiential learning, in which a learner has concrete experiences, reflects on those experiences, and thereby builds more abstract understandings (Kolb, 1984).

Early research on Palmagotchi (Klopfer, 2008), an example of a mobile casual learning game and a precursor to UbiqGames, suggests that such experiential learning can be facilitated by this type of game. In Palmagotchi (Klopfer, 2008), students cared for and mated virtual birds while observing how heritable traits impacted their own lineage of birds specifically and the cumulative population of all birds managed by all players in general. Gameplay took place on wireless mobile devices carried with students throughout the day. During the pilot study, gameplay provided concrete experiences and took place primarily outside of class time. This out-of-class play was followed by in-class facilitated reflection and discussion of game strategies and data generated by gameplay, culminating in increased student understanding of core concepts. Initial research demonstrated that students appeared willing and able to play the game interstitially outside of class. Students also engaged in in-class reflection of data generated through student gameplay. However, research around Palmagotchi was limited, particularly by the lack of rich, automatically generated data available for in-class discussion. As well, server logs were not well constructed which made it difficult to get substantial data regarding gameplay patterns, a key element to understanding the adoption of UbiqGames. Subsequently, to build the possibilities for experiential learning and useful research, designing effective data aggregation tools for in-class reflection and logging relevant gameplay data on the servers has become an important priority for UbiqGames such as Weatherlings and others in development.

1.1 Research Questions

This research study sought to determine the feasibility and general efficacy of a novel Ubiquitous Games approach, in which students played educational games voluntarily outside of class time. In particular, the goal was to find out whether students were engaged with the game and with the topics the game was designed to help students learn about. To examine this, researchers collected data to answer several more targeted research questions, including:

- RQ1. What usage patterns emerged regarding time of day, frequency, duration and location of gameplay?
- RQ2. As a multi-player game, what patterns of peer-to-peer interaction emerged?
- RQ3. Did Weatherlings motivate student interest in weather, specifically climatology and meteorology?

1.2 Description of Weatherlings

Weatherlings is an online collectible card battle game designed to be played on mobile devices, but able to be played on any computer with a web browser. In Weatherlings, players manage a collection of cards representing weather-dependent creatures, and pit decks of their cards against other players' decks in battles. These battles are set in actual U.S. cities for which the development team has collected real weather data from the recent past.

When a player joins Weatherlings for the first time, they use a special code which assigns them to a particular instance of the game, typically with other players from their class, school, or after-school group. Upon logging in to Weatherlings, a player has four options: go to the Headquarters, Trunk, Store, or Lobby.

In their Headquarters, players can check their win-loss record, review results from past battles, see any special awards they may have won, and send messages to other players. In the Store, players purchase new creature cards to add to their collections. As players advance in level, they have access to more powerful creature cards through the Store.

In the Trunk, a player organizes and learns about his or her creature cards. There, each player can see the randomly assigned cards received when they started the game, along with any cards

purchased from the store. More importantly, players prepare decks of cards in the Trunk. Decks are sets of ten or more cards used for individual battles. Each card in the game has one of five affinities: hot, cold, wet, dry, or normal. Normal cards have no weather effect on their moves, while the other four affinities have moves that reflect those affinities. So, when preparing for a battle in a warm, rainy location, a player might choose to build a deck of cards with hot and wet affinities. Players can build as many decks as they choose, and individual cards can be in multiple decks at once. Ideally, a player would have at least one deck for each type of climate in which they might battle.

The last main area in Weatherlings is the Lobby, where players join or initiate battles. Battles take place between pairs of players, but a single player can be part of more than one battle at once. When setting up a battle, the player starting the battle has a choice of how many rounds will be played in the battle, within a preset range (usually five to fifteen rounds). After a player sets up the battle, that battle goes into the queue of battles that other players can join, and the first player waits for a second player to challenge them.

After the second player has joined the battle, the players select the arena where the battle will take place. An arena is a real U.S. city for which authentic weather data from the recent past has been programmed into the system. To keep the selection process equitable, three cities are proposed, and each player has the option of removing one of those cities from contention. If players remove two different cities, the third city becomes the arena. If the players both choose to remove the same city, the system randomly selects one of the remaining two. To help players make an informed choice about which city to eliminate, they are presented with a brief description of the city and a climate graph that shows monthly average temperatures and average rainfall for each possible city. Strategic players will attempt to play in the city whose climate best matches the characteristics of the card decks they have prepared.

After the arena location has been determined, each player chooses the deck with which they will play. Ideally, this deck will have cards that perform well in the climate of that arena. Once players select their decks, the battle begins.

At the start of each battle, players can see weather data for two days leading up to the battle. This data includes time of day, temperature, wind speed and direction, relative humidity, and barometric pressure, as well as regional maps of weather fronts, temperature, and cloud cover (see Figure 1).

In the battle, the first round culminates with a skirmish that takes place six hours later than the last data point players have seen. After that skirmish takes place, the weather data to which players have access is updated to include everything up to the time of the latest skirmish. That means that after each round, six more hours of weather data for the arena are revealed.

With weather data available to inform their play, players start the first round of the battle. A battle round consists of five parts: (1) the optional step of making a weather prediction; (2) drawing a card from their deck into their hand; (3) playing a card from their hand onto the playing field; (4) choosing a card from the playing field to use, choosing which of that card's moves to use, and choosing a target for the move; and (5) seeing the results of the skirmish.

Figure 1. Weatherlings weather data (left) and creature card (right)

The prediction system is one of the newer parts of the game, added after formative play tests to encourage players to make explicit predictions about the weather, and to better enable researchers and teachers to assess players' weather prediction skills. This system allows players to predict the temperature and whether or not there will be precipitation at the time of the skirmish. If their temperature prediction is within two degrees Fahrenheit (one degree Celsius), and the precipitation prediction is correct, the player receives an in-battle bonus, such as added damage in the next round, added game points, or reduced damage to their cards.

In the battle, the cards from the deck with which the player is playing are shuffled randomly, and in each round the player draws a new card to add to their hand. Also in each round, each player has the option of playing a new card from their hand to the battlefield. On the field, cards can be attacked and disabled, but can also attack the other player's cards.

After playing a card to the field, each player chooses which card they will use in that round and which move of that card to use, either an attack move against one of the other player's cards or a healing move that affects one of their own cards. Weather plays an important role in a player's choosing the best card to play and which move to use because cards' moves are weather dependent. For example, Summer King (see Figure 1), is a card with a hot affinity, and has a move, Flare, that can only be used when the temperature in the arena is over 60 degrees Fahrenheit, but does extra damage when the temperature is more than 80°F.

At the end of each round, players see details of the skirmish, including how much damage their cards did, how many battle points they were awarded (one point is awarded for every ten points of damage done, with bonuses awarded for disabling an opponent's creature and for prediction accuracy), and if they were correct in their weather prediction or not.

The battle continues in this manner, round-by-round, until the set number of rounds has been completed, or until one player forfeits.

At the end of the battle, the winner is the player who has accumulated the most battle points. Though the winner earns more, both players receive game money and experience points (XP) for completing the battle. Accumulating enough XP allows players to level up and access more advanced cards in the store, while players can spend the game money they earn at the Weatherlings store to buy more virtual cards and build stronger decks. An important note about the more advanced cards is that they also require more advanced weather prediction skills to be used most effectively since the moves of more advanced cards work in a narrower weather range than the moves of basic cards.

In addition to the student view of the Weatherlings game, teachers are able to access a whole-class view of the game, which includes access to all battles that have taken and are taking place. Teachers are able to observe individual students' progress, as well as trends throughout their class or classes to see what weather concepts are understood, and which could use more review.

2. METHODOLOGY

2.1 Sample

Twenty Singaporean students aged 10 or 11 were recruited from a single classroom to participate in a research study. Participants included 12 boys and 8 girls, selected by their teacher from a larger class of 40 total students. Students participated voluntarily and participation was not graded. Survey data indicated that all participants (100%) played electronic games, and when asked how much they like playing electronic games, most students (95%) indicated high levels of interest in games. When asked what type of electronic games they play most often, the majority of students (60%) answered that they play computer games most frequently in contrast to other types of games, e.g. PSP (10%) and mobile games (10%). Prior to playing Weatherlings, students were also asked to share their level of interest in learning more about weather. In response, 45% of students said that they were 'very interested,' with an additional 45% 'interested' and 10% 'neutral.'

2.2 Methods

Over the course of the four-day research study, students borrowed mobile devices (Android based HTC My Touch or Android based G1 devices using 3G data plans, all running Android 1.5) which provided them anytime, anywhere access to Weatherlings via the browser.

On Day 1, students were given an introduction to the hardware and basic tutorial about the game goals and game mechanics. During this two-hour introductory session, students also completed a written pre-survey. Since the cities (and their corresponding weather data) used in Weatherlings are located in the United States, researchers provided the Singaporean students with a brief overview of differences in geographic location, size, latitude, and weather between Singapore and the United States. Focusing on temperature ranges and chance of precipitation (two key factors in Weatherlings), researchers compared forecasts for Singapore and Boston for the upcoming week. Students also received a paper-based weather tutorial, which explained relevant weather information contained in the game and were told that this tutorial could be useful for game strategy. Beyond this, however, students did not receive any formal weather instruction. Participating students were not studying weather in class, nor had they recently studied weather. After the brief in-person tutorial, students played the game, but then were explicitly told not to bring their devices to school, so as not to be disruptive to classes. Students were instructed to play Weatherlings as much (or as little) as they liked over the next three days. On Days 2 and 3 students played the game, and on Day 4, researchers again visited the classroom, this time conducting a follow-up discussion with the group of participants, each of whom also completed a written post-survey. The study concluded midday on Day 4, limiting the amount of gameplay on that day. Throughout the study, the game server tracked students' interaction with the Weatherlings software.

3. FINDINGS AND DISCUSSION

3.1 Gameplay Patterns

Weatherlings was designed to be played outside of class time over the course of multiple days. If Weatherlings and similar Ubiquitous games are to be feasible, students' play patterns should reflect players' interest in engaging with the game outside of school, sustained over several days. As such, researchers were curious to observe play patterns, particularly those which illustrate when students played, how often they played, and where they played.

An analysis of the server logs, which automatically track players' actions, provides a substantial amount of data regarding gameplay patterns. Over the four days of active gameplay, the 20 participating students played a total of 194 battles and a total of 1264 rounds. Of these, 136 battles were completed (i.e. players finished the full number of preset rounds), including 883 rounds. The average battle consisted of 6.42 rounds. The average round lasted approximately 62 minutes, with the average round length for completed battles lasting 56 minutes. Further review of the server logs revealed that the average time it took to complete a round was affected by the number of days the battle spanned. While most battles were completed on the day they began, other battles spanned two or even three days (see Table 1).

Table 1. Average Length of Rounds Separated by Time Span of Battles (in days)

Duration of Completed Battles	Average Length of Round (in minutes) (SD)
Spanning 1 Day (n=103)	10.31 (23.12)
Spanning 2 Days (n=31)	185.35 (74.75)
Spanning 3 Days (n=2)	424 (116.75)

Not surprisingly, battles which took place in a single day (no overnight) were substantially shorter than those which spanned an overnight. For the rounds completed in a single day, the average length was just 10.31 minutes.

Server log data also demonstrate that students continued to play across all four days of the play test (see Figure 2). Note that Day 4 ended before the peak afternoon/evening flurry of gameplay typical on the other three days.

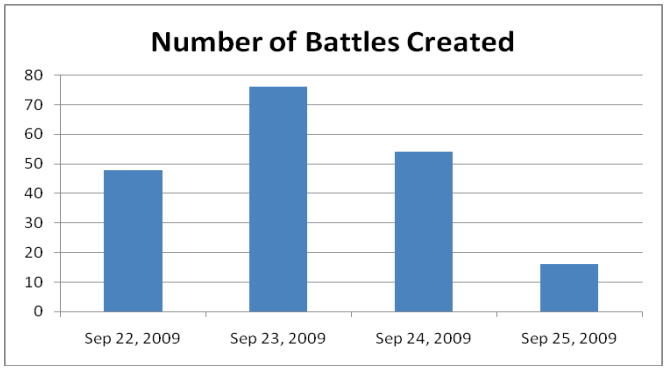

Figure 2

Students played Weatherlings (primarily) outside of school hours (see Figure 3). This graph corroborates student self-reporting, showing that peak hours for gameplay were afternoon and evening.

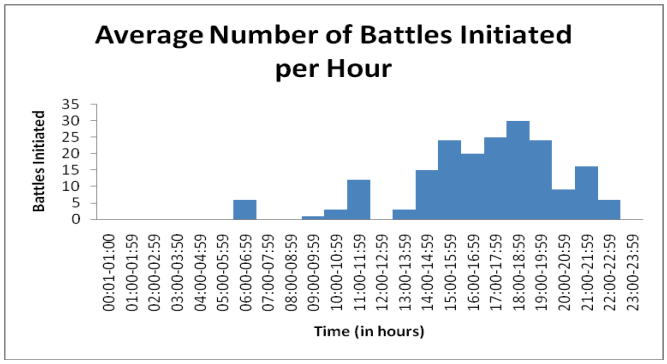

Figure 3

In the debrief session, when students were asked when they tended to play, responses included "after school" (75%), "I snuck it and played at or on my way to school" (40%), and "after dinner" (60%). No students reported playing before school (though data logs show a few battles initiated in before-school hours, see Figure 3). When asked about where they had played Weatherlings, students reported playing in their bedroom (70%), in a public place in their house (50%), and outside (35%).

When asked how many decks students created, 25% of students reported creating only one deck, while 40% created two or three decks, and 15% created four or five decks (n.b., not all students responded). More than half of the students (55%) also reported making changes to existing decks at least once per day.

The above data suggests strong student engagement and appeal of the game. To corroborate this data, students were asked in post-survey questions to rate their experience playing Weatherlings. All (100%) of participants thought Weatherlings was 'fun.' When asked to elaborate as to why, student responses varied, but included descriptions of the game as 'fun yet educational,' 'challenging,' 'sustaining their interest,' 'enjoying the battling,' 'picking up game skills,' 'creating decks,' and 'playing with friends whom they have less opportunity to interact with.' When asked if they would like to play Weatherlings again, all (100%) said they wished to play the game again.

As part of Weatherlings, players can make optional weather predictions (about temperature and precipitation) and are rewarded if their prediction is accurate. In all battles (complete and incomplete) 1158 predictions were made in 1962 opportunities, or 59.0% of the time. When tracked by day, students continued to make predictions across all four days of gameplay (see Figure 4).

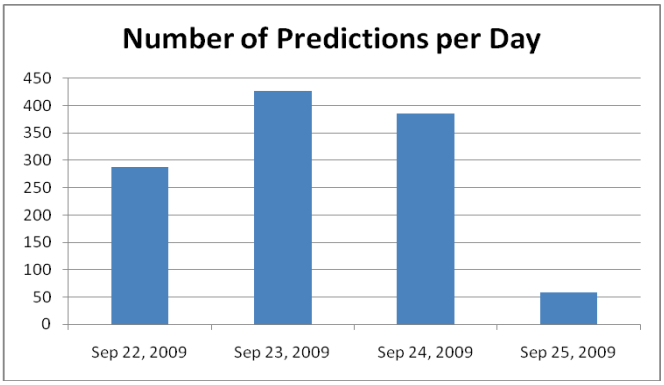

Figure 4

Using server data, researchers analyzed the difference between students' predictions and the actual weather data to see whether or not students' prediction skills improved over the course of the game. It was found that there was no significant improvement (or decline) in students' forecasting abilities as measured by their prediction accuracy.

3.2 Peer-to-peer Interactions

Since Weatherlings is primarily played in head-to-head pairings of players, researchers collected data regarding the nature of student pairings. Data show that the average student had 9.6 unique opponents (S.D. 4.02). During the debrief discussion, students reported that they not only played against their friends (60%), but also played against whomever was available (75%).

3.3 Motivation of Student Interest in Content Domains

Students were asked what they wanted to know or learn more about weather after playing Weatherlings. As shown in the graph below (see Figure 5), several (27.3%) said that they hoped to learn how to make accurate weather predictions, while other students (18.2%) wanted to improve skills reading weather maps.

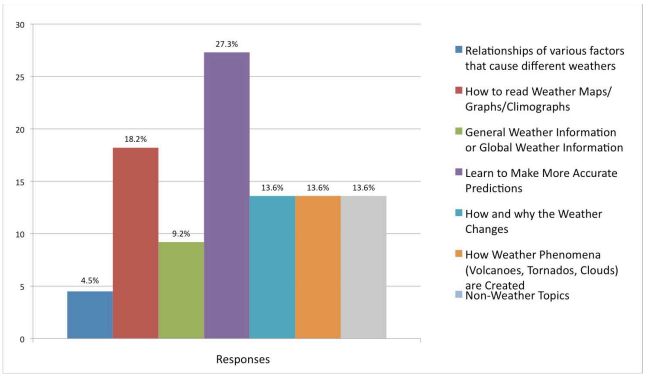

Figure 5. Weather-related information which students hoped to learn after playing Weatherlings.

Participants were also asked generally whether or not after playing Weatherlings they were interested in learning more about the weather. A large majority (90%) of students were 'very interested' or 'interested' in learning more.

3.4 Conclusions

This research study sought to evaluate a new paradigm for educational technology, the UbiqGame. These ubiquitous browser-based games, such as Weatherlings, enable students to engage in challenging, thoughtful activities which foster learning anytime, anywhere via mobile technology. Initial findings presented here demonstrate that students were indeed able to use "interstitial time" outside of the traditional school day to play this type of game, and that this particular game sustained their engagement and piqued their interest in meteorology/climatology.

While server data tracking the accuracy of student weather predictions does not demonstrate improvement over time, further analysis of the data could examine whether or not students' selection of decks, cards, and card moves demonstrate improved conceptual understanding of climate as well as the ability to predict weather with the accuracy needed to take advantage of card moves and therefore perform better in the game.

Data reflecting peer-to-peer interactions shows an interesting trend toward students playing with whomever is available, rather than simply with their close friends. Further analysis of the data could explore whether gender and other factors (skill at the game) also played a role in students' selection of opponents.

While these initial findings are promising, the study also raises additional questions. The sample of students in this study were likely predisposed to games and technology (though one might argue that they might therefore be more critical of a substandard game). To be more broadly applicable, additional research should include students for whom mobile technology and electronic games are not as commonplace.

Additionally, while motivation and engagement outcomes were demonstrated, evidence of learning (beyond self-reporting) was not clearly demonstrated. We hypothesize that this is likely the result of this pilot study's emphasis on gameplay rather than weather content. Future versions of the game will be designed with in-game tutorials in which players will explore weather-specific content, learning about a concept and then adding cards whose moves take advantage of understanding those concepts. With the inclusion of in-game, content-specific tutorials, additional research around content learning should be undertaken to better assess whether or not this has an effect on learning outcomes.

Another factor to consider is that students were explicitly told to leave their mobile devices at home, so as not to disrupt the school day. However, the portable nature of a mobile device has the potential to create additional learning opportunities including increased times for gameplay, particularly face-to-face collaboration/competition with peers. Additional research in which students bring their devices with them everywhere will likely shed useful light on other ways in which the ubiquity of these games can provide additional opportunities and potentially improved learning outcomes.

Finally, and perhaps most importantly, comes consideration of the context in which a UbiqGame should be used most effectively. These games are designed to be used alongside classroom instruction on the topics considered in the game. In this study, with the exception of an introduction and closing discussion, Weatherlings largely stood on its own without substantial teacher support or integration in the classroom. There are likely many ways in which teachers could amplify the impact of students' use of the games by leveraging class discussion and reflection upon gameplay, students' strategies, and data generated from the games. Such integrated experiences are a rich area for research since many questions as to how to weave these games into the larger learning environment remain.

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