Rani, N., Chu, S. L., & Williamson, Y. G. (2024). Supporting lifelong learning: Comparing an in-situ and a post hoc approach to support everyday question-asking. *Educational Technology & Society*, *27*(2), 256-269. https://doi.org/10.30191/ETS.202404_27(2).RP11

Supporting lifelong learning: Comparing an in-situ and a post hoc approach to support everyday question-asking

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(Submitted June 1, 2023; Revised October 31, 2023; Accepted November 19, 2023)

ABSTRACT: Much of lifelong learning is driven by our curiosity to ask ourselves questions about the things around us in everyday life. Unfortunately, we often fail to pursue these questions to acquire new knowledge, resulting in missed opportunities for lifelong learning. We investigated two approaches to technological support for lifelong learning from question-asking in everyday life: an in-situ approach – reflecting and learning in the situatedness of the moment when a question is asked, and a post hoc approach – self-reflecting and learning after the question-asking moment when one is available to reflect. The in-situ approach may enable people to tap into their embodied experience to gain understanding, while a post hoc approach may allow people to allocate greater cognitive and material resources to explore and understand. We implemented two systems embodying each of the two approaches. A study was conducted to compare the use of the two learning support systems in an everyday virtual environment. Results showed that the post hoc approach produces more curiosity questions and reflection than the in-situ approach. We discuss the implications of our results for the design of systems to support lifelong learning.

Keywords: Lifelong learning, Question-asking, Situated Learning, Reflection, Context

1. Introduction

In our current educational system, learning is often confined to fixed spaces and times. Whether formal or informal, learning is said to happen mostly, for example, when we are in the classroom during school hours or during a visit to the science museum. Yet, learning is a very embodied activity that can happen at any time and any place. This idea of learning without spatial and temporal boundaries has been explored under the umbrella term of lifelong learning or everyday learning. Learning is seen to be no longer limited to school contexts. Lifelong learning is a self-motivated learning process that happens in daily life and throughout all of one's life (Kalz, 2014). Much of lifelong learning is driven by our desire to know and understand new things. Question-asking is a core driver of lifelong learning (Medel-Añonuevo et al., 2001). Throughout the course of our everyday life, we often wonder about things in our environment – for example, why is the sky blue? Why does trash smell bad?

Unfortunately, we often do not pursue these questions that we ask of our everyday surroundings. This creates missed opportunities for lifelong learning. Some reasons for not exploring everyday questions are not having the information source or technological support at hand, not having the time at the moment to explore (Ottenbreit-Leftwich & Kimmons, 2020; Rani et al., 2021), being involved in another task while curiosity occurs, postponing exploring the questions and later forgetting about it, etc. Sometimes there may be a lack of motivation or drive to pursue exploration. There hardly exists any system to overcome these hurdles and support our pursuit of self-motivated everyday questioning, despite the persistent presence of technological devices that we carry with us, like smartphones and smartwatches with internet access. We propose that there are two ways that technological support can be provided to help one in pursuing everyday questions. For the first approach, the learner is supported to pursue their questions right at the moment of questioning. We call this the in-situ approach. The second approach provides support to the learner to quickly capture the context when questions arise, and to then recall the questions and pursue them at a later time when time and resources are available. We call this approach the post hoc approach. The in-situ approach tends to be the typical approach used for designing mobile apps, with technological support being provided at the moment of need. The post hoc approach is related to past work on supporting recall and reflection, but the literature here tends to focus on technological support for lifelogging (e.g., Rennert & Karapanos, 2013), support for people with memory impairments (Lee & Dey, 2008; Sas et al., 2013), or as support for data collection in user experience research (e.g., Arvola et al., 2017).

One of the main problems with formal and informal learning is a lack of motivation to engage the learner (Milner et al., 2011). With lifelong learning, however, learning tends to be intrinsically motivated since one pursues learning based only on what one is interested in or curious about. Lifelong learning thus has great potential to catalyze the learning of a wide range of concepts (for example, the foul odor of everyday trash is related to the scientific process of material decomposition). Supporting one's motivation to ask (and seek answers to) questions with respect to things in one's environment, thus, can lead to learning new concepts related to science, technology, history, etc., under the lifelong learning paradigm (Wu et al., 2018).

This paper presents two studies, a preliminary study and the main study, that we conducted to investigate technological support for the in-situ and post hoc approaches to everyday question-asking. The preliminary study was conducted to inform the design of the post hoc approach that relies on supporting the user to recall questions that were asked at a prior time. In the preliminary study, we explored 8 different types of cues (image, action, location, etc.) that can potentially facilitate recalling of a question-asking moment. We then designed two systems that allowed people to pursue everyday question-asking for learning of science concepts, one for the in-situ approach and one for the post hoc approach that used findings from the preliminary study. Using the two systems, a main study was conducted to investigate the effectiveness of each of the two types of approaches. Because of the COVID-19 pandemic, the main study was conducted in a virtual setting using a teleconferencing software, and 360◦ images were used to create a virtual environment. However, we believe that the insights from the study remain applicable to inform us about technological support for everyday question-asking.

2. Background and related work

Type the label There is no universal definition of lifelong learning. Broadly speaking, lifelong learning emphasizes (i) continuous learning; (ii) existence of support; (iii) self-motivated learning; (iv) added knowledge or value or skill; (v) learning in all types of the environment; (vi) applied and used information; and (vii) positive experience, (Duyff, 1999) as cited in (Collins, 2009). Asking questions is often seen as a critical activity in pursuing lifelong learning. In discussing how to develop students' capacity for lifelong learning, Riley and Claris (2008) state that teachers should encourage students to ask the simple question of "why" in order to get them to higher order thinking. While lifelong learning has obvious benefits, there are some critical challenges that people face in engaging with it. Some of these challenges are time constraints (learning in a lifelong manner may interrupt daily activities), lesser engagement (narrowed experience due to constant involvement) (Ottenbreit-Leftwich, & Kimmons, 2020), lack of motivation, and lack of resources (Collins, 2009).

There is some work exploring technological support for lifelong learning. Sharples (2000) and Fischer (2000), notably, have proposed frameworks and requirements of lifelong learning support (Fischer, 2000; Loureiro et al., 2012; Sharples, 2000). Tools that support lifelong learning should be portable (carried in the various environment), personalized (adapt to an individual's ability and requirements), contextualized (aware of one's context), unobtrusive (allow learning without constraints), available, persistent, have built-in expert support, useful, have a reflection mechanism, etc. (Fischer, 2000; Sharples, 2000). In our work, we are interested in supporting everyday question-asking as a pathway to nurture lifelong learning.

This specific work looked at comparing an in-situ and a post hoc approach to technological support for everyday question-asking. An in-situ approach is grounded in theories like situated learning and embodied cognition. Situated learning theory posits that learning is anchored in the concrete situation in which it takes place (Anderson et al., 1996). Embodied cognition theories suggest that learning is not purely a cognitive process, but that the body plays a significant role in learning. The mind and body function as one whole to enable learning. Concepts are motorically as well as semantically processed by the brain (Shapiro & Stolz, 2019). For example, seeing people dancing may trigger the parts of the brain associated with moving. Both situated learning and embodied cognition theories thus suggest that the in-situ approach may lead to better reflection than the post hoc approach since the user reflects and explores a question asked in the situation where the question is relevant, with all the details of the context fully available for perceptual and sensory uptake. Conversely, the post hoc approach should fail to provide the benefits of situated and embodied learning. However, it is aligned with reflective learning practices that suggest that stopping and thinking about past experiences and situations is necessary for learning to occur (Thorpe, 2004). Reflective learning is discussed in the context of experiential learning where the learner engages in active experiences and then pauses to reflect on them. Therefore, the post hoc approach, which involves the learner engaging in reflection to learn after the experience has passed, may lead to better reflection.

In terms of technological support, systems that are the most related to an in-situ approach are often developed to support the Experience Sampling Method (ESM) (Larson & Csikszentmihalyi, 2014). ESM has, in the early days of the method, been implemented through the reporting of experiences in paper diaries in the moment

(Delespaul, 1995). Nowadays, implementations of the ESM are in the form of applications in personal assistants (Csikszentmihalyi, 2011), and smartphones (Milesi et al., 2017). These mobile phone applications allow users to note and report their experiences on the go and in different environments (Larson & Csikszentmihalyi, 2014). Some examples of such ESM applications are Experience Sampler (Thai & Page-Gould, 2018) and LifeData (see https://www.lifedatacorp.com/).

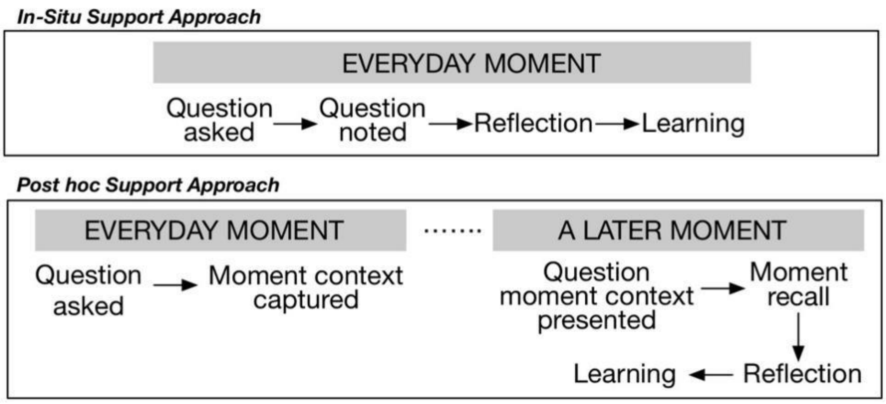
Systems that implement a post hoc approach are usually lifelogging systems that support recall of prior moments. Life-logging systems capture everyday moments and are meant for revisiting memories, events, sharing moments, tracking personal habits, etc. (Niforatos et al., 2017). Despite having the potential to support learning in daily life through exploring everyday moments, these systems are not designed to support reflection and learning. A few aims to support learning. For example, Li et al. (2012a) developed an application called scroll that aims to help users recall what they have learned by capturing learning logs using contexts and the learners' learning habit. They found the scroll to be effective in English vocabulary learning. Another study by Ehlen et al. (2008) explored the use of a recall interface to support the recall of information for the meeting using the captured information from past meetings that could be relevant. They explored the interface to investigate how to present and visualize captured information and found that some abstracted information may be useful and showing a timeline of information may be useful. Mutlu (2015) designed, developed, and tested a lifelogging system that supports lifelong learning by capturing everyday learning experiences through webcam images and screenshots of individual's laptops and tablets. There are only a few explorations investigating the use of logging techniques for lifelong learning to assist in everyday learning. Even then, none of these explorations investigate a basic form of lifelong learning where learning happens in everyday life without explicit intent, such as everyday curiosity-based question-asking.

3. In-situ vs post hoc approaches to everyday question asking

The two approaches to everyday question-asking support that we investigate can be distinguished based on when they foster reflection. Ferreira (2017) proposed two types of reflection: reflect-in-action and reflect-on-action. Reflect-in-action means reflecting simultaneously while performing an everyday task (the in-situ approach), whereas reflect-on-action means recreating the moment after the moment passes, then reflecting on thoughts and learning through reflecting on past experiences (the post hoc approach). The in-situ approach, as we conceptualized it for everyday question asking support, is illustrated in Figure 1 (top). In that approach, a user can think of a question during a moment in everyday life, and capture the question, reflect on it and obtain responses to the question right during that same moment. Conversely, in the post hoc approach (Figure 1 (bottom)), the user thinks of a question during a moment in everyday life, but only has the context of the moment captured at that very moment. At a later (perhaps more appropriate) moment then, the user is made to recall the question-asking moment through the presentation of the context details of that moment, and then is asked to reflect on it and learn from it.

While the in-situ approach is rather straightforward, the post hoc approach requires a more complex design to first support the recall of an everyday moment through the presentation of context details. This led us to conduct a preliminary study to inform the design of the post hoc approach, as described in the next section.

Figure 1. In-situ VS Post hoc support concept



4. Preliminary study

We conducted a preliminary study to explore the prerequisites for the design of a post hoc support application for everyday question asking. This study explored the effectiveness of different contextual cues in recalling a question-asking moment. A contextual cue is anything associated with an environment or context that may help a person retrieve memories of that environment at a later time. The possibility of using contextual cues for context recall is based on theories of context-dependent memory. Through many studies, human memory has been generally found to be dependent on the incidental details of the environment in which an event takes place (Smith & Vela, 2001). Thus, presenting the details of the environment may facilitate a person to recall the event itself. However, for the purpose of system design, we were interested to know which contextual detail would support event (or moment in our case) recall the best.

Eight types of contextual cues were chosen to be explored for this study: (i) the action the participant is performing during the question-asking moment (Cardozo, 2015); (ii) the emotion of the participant during the question-asking moment (Dingler et al., 2016); (iii) the specific object that the participant is looking at (Dingler et al., 2016; Li et al., 2012b); (iv) the image of what the scene that was in front of the participant during the question-asking moment (Dingler et al., 2016; Li et al., 2012b); (v) the location where the question-asking event occurred (Cardozo, 2015; Jaimes et al., 2004); (vi) any people who were present during the question-asking event, (vii) the physiological state (heart rate) of the participant during the question-asking event (Dingler et al., 2016); and (viii) the time when the event occurred (Cardozo, 2015; Jaimes et al., 2004). The research question we pursued in this preliminary study, thus, was: *what are the most effective cues to help people recall a moment of everyday question-asking?*

This study was approved by the University ethics board. A total of 11 participants (6 females and 4 males) participated in the study. This was a two-part study. First, participants were asked to visit a few places on campus and explore the environment. They were asked to voice out questions that come to their mind on things that interested them or piqued their curiosity while exploring the places. When participants generated a question, context cues were captured about the moment. The context cues were captured for this study through the following approaches: action, time, and emotion cues were obtained from a video recording that a researcher took of the participants as they visited the places. The researcher shadowed the participants to take the recording but did not interrupt the participants' processes. The participants' action during question-asking was interpreted from the video recording. The timestamp at which the participants voiced out a question was noted. Images of the participants' facial expressions during question-asking were extracted from the video recording, and processed through Affectiva (see https://www.affectiva.com/), an emotion recognition software, to determine emotion. Scene image, object, location, and people cues were captured through a smart camera called Ion Snapcam (see https://manuals.plus/ion/ion-snapcam-wearable-digital-camera-user-manual). that was attached to participants' shirt's collar with a clip at the beginning of the study. And lastly, the physiological (heart rate) cue was captured through a smart wristband (see https://www.empatica.com) that the participants were also made to wear.

Figure 2. Recall interface used in the preliminary study
(Left) 8 different contextual cues used to support recall of question-asking moments; (Right) Example cues for a particular question-asking moment

The second part of the study was scheduled with participants the next day (or the day after if participants were not available the next day). It was the next day to have some time gap between moment capture and recall, so recall is not due to immediate memory but also not too long that it has to use long term memory. In that session, they were asked to use an interface (Figure 2) that presents the contextual cues captured in the first part of study to recall question-asking moments, and type in the questions that they asked while visiting the campus places. The context cues were presented one at a time, and the participants could type in their question at any point of time during the presentation of the 8 cues. Participants then filled out a post-study questionnaire.

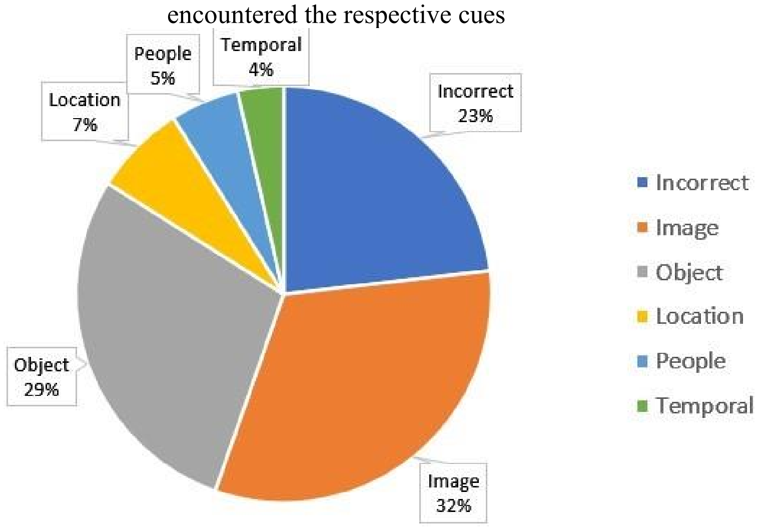
In response to "At which cue were you the most confident of your question?" participants rated image (61.8% of the times), object (23.9% of the times), and location (10.9% of the times) as the most important cues. Participants were asked to rate on a seven-point scale the degree of helpfulness (1 – "extremely unhelpful"; 7 – "extremely helpful") of each cue to recall their question. The helpfulness average ratings of the cues are shown in Table 1 below.

Table 1. Average helpfulness ratings for 8 cue types

Cue Type	Avg Rating (1 – 7 scale)
Image cue	6.2
Object cue	5.6
Location cue	4.9
People cue	2.6
Action cue	2.4
Time cue	2.2
Emotion cue	1.7

Li et al. (2012b) investigated lifelogging tool to support ubiquitous learning that captures learning experiences by allowing users to log audio, videos, images, RFID tags. Li et al. (2012b) made similar observations for cues' helpfulness in recalling. We also compared all the recalled questions in the interface against the original question that were voiced out in the first part of the study (transcribed from the researcher's camera recording) to measure recall accuracy. Questions that matched in words or meaning were marked correct. The overall accuracy of 78% was reported in recalling questions using all the cues. During the study cues were presented to the participants one after another in a random order and they could update their recalled question each time. Figure 3 shows the times participants recalled their question correctly for the first time with cues. The chart in figure 3 can be interpreted as 32% of the time it was an image cue which helped participants recall the question correctly for the first time and so on.

Figure 3. The percentage of times participants recalled their questions correctly for the first time when they encountered the respective cues



5. Main study

We conducted the main study to investigate the impact of post hoc and in-situ approaches for everyday question-asking and reflection. We used the cues identified in the preliminary study to design the recall interface for the post hoc approach.

5.1. Research questions

The research questions addressed in the main study were:

- RQ1: Is there a significant difference between the post hoc approach and the in-situ approach to technological support for everyday question-asking in terms of encouraging users to capture everyday questions?
- RQ2: Is there a significant difference between the post hoc approach and the in-situ approach to technological support for everyday question-asking in terms of encouraging users to engage in reflection to everyday questions?

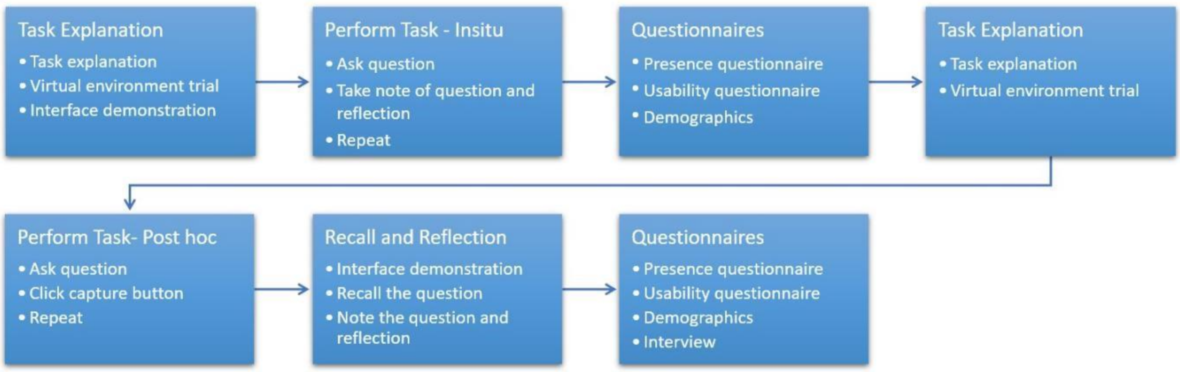
5.2. Study design and procedure

The study was approved by the university ethics board. Participants were compensated with course credit for completing the study. A departmental study participant pool was used to recruit 30 participants for the main study. The participants consisted of 25 male and 5 female participants (average age: 20.8 years; range: 18 to 26 years old).

The study was conducted in an online setting through teleconferencing software due to the limitations posed by the COVID-19 pandemic. A within-subject study design was used, with counterbalanced conditions. The single independent variable of the study was Immediacy of recall and reflection to question-asking, with two levels: post hoc approach and in-situ approach. The study procedures are shown in Figure 4. In the study, participants had to navigate through and explore different virtual environments of given locations and ask questions about things that may be interesting to them, similar to the preliminary study. In both conditions, the virtual environment was created using 360◦ images to confer a sense of presence. There were two types of environments, a roadside and a theme park. Two sets of 360◦ images were chosen for each type of environment. In other words, we had two locations at a roadside and two locations at a theme park.

The procedures for both conditions were generally the same. Participants were first briefed about the study task and shown how to use the system associated with the condition they were about to engage in. Participants were shown how to move through a 360◦ virtual environment using a test location. Along with exploring the environment to ask questions, participants were asked to count the number of garbage bins they observed in the environment as their main task. The garbage bins counting task was given so as to replicate having a simultaneous task at hand, as happens in daily life (one does not go through daily activities simply seeking to find questions to ask – rather questions typically arise as one engages in other needed activities). Participants had to speak their questions out loud. In the post hoc condition, participants would click the Capture button (see System Description section) to capture the contextual cues during the question-asking moments. In the in-situ condition, whenever participants voiced out a question, they would immediately use the Notes interface to write down their question, reflection notes, and investigate more if desired. Participants continued exploring the environment till they finished the task of exploring, asking questions, and counting the number of garbage bins.

Figure 2. Procedures for the main study



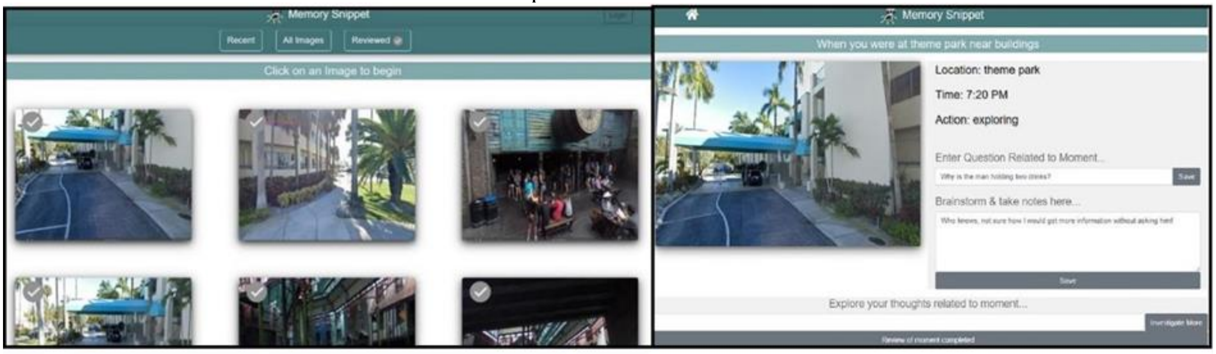
For the post hoc approach, the study spaced out question-asking and recalling questions by asking participants to fill out a survey as a distraction after the environment exploration phase. After taking the survey, participants used Memory snippet (see System Description section) to recall each of their questions using the contextual cues presented. reflect upon them and investigate further if desired. For both conditions, participants were free to ask as many questions as they wanted and to take as much time as they needed to explore the environment and to complete the study task. At the end of each condition, participants filled out a post-condition questionnaire and participated in an interview.

5.3. System description

We designed and implemented two systems, embodying each of the two approaches.

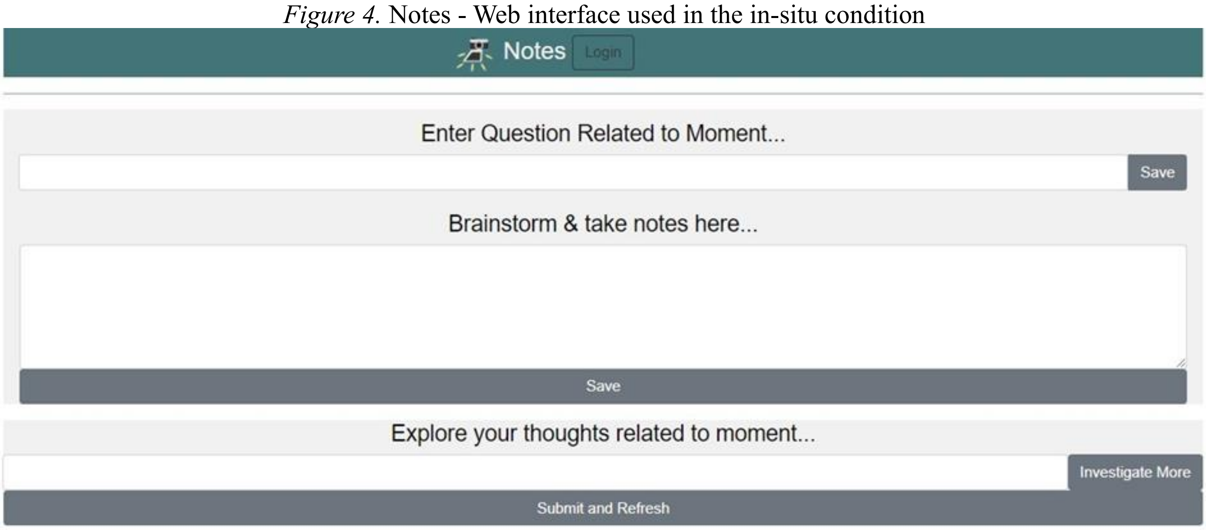
A capture button interface was used to capture contextual cues while exploring the virtual environment. This interface appeared in the top left corner of the virtual environment. It had a button called the capture button. Whenever participants wanted to capture the moment when the question arose in their minds, they clicked the capture button, and the context for that moment was captured. This button captures the screenshot of the environment of the moment, the timestamp, and the type of the environment. This interface was only used for the post hoc approach as it required the capturing of moments for later recall.

Figure 3. Memory Snippet: Web interface used in the post hoc approach condition
Note. (Left) Home screen showing image cues from all moments captured; (Right) Details screen for one of the captured moments.



The system used in the post hoc approach for recall and reflection is called Memory Snippet. The main page of the interface (Figure 5 left) for the post hoc condition consisted of a list of image cues corresponding to all the question-asking moments captured by the user. The image cue was chosen as the primary cue in the interface since it received the highest average ratings in our preliminary study. On clicking on an image cue, all the other cues related to that moment are presented to the user to help in recalling the question-asking moment (Figure 5 right). That screen also has a text box where users can enter the question they asked after recalling the moment of question-asking, and further enter reflection notes in the "Brainstorm and take notes" text box. After recalling their question and typing in reflection notes if desired, the user can click on an "Investigate more" button to navigate to a search engine preloaded with the user's question as search terms to explore the question.

Figure 4. Notes - Web interface used in the in-situ condition



The system used for the in-situ approach for reflection was called Notes (Figure 6), and was designed to be the same as the Memory Snippet interface in look and feel, except that it did not present moment context cues to the user (since it was intended to be used right when a question is conjured). Other than the context cues, the Notes interface had the exact same features as Memory Snippet, allowing users to enter their question, type in reflection notes, and use "Investigate more" to explore their question.

5.4. Measures

Based on our research questions, two main dependent variables were of interest: Extent of questions capture, and Degree of engagement in reflection. The extent of questions capture was measured using the count and type of questions that the participants entered in the study support interfaces (Memory Snippet and Notes). To evaluate questions captured appropriately for the post hoc approach, we also measured the degree of question recall since the questions participants entered in the interface would be dependent on how well they recalled their questions in the first place. Question recall was assessed by comparing the questions that the participant asked out loud during exploration to the recalled question as typed into the Memory Snippet interface.

Degree of engagement in reflection was measured using the following: (i) number of times reflection notes were taken by the participant, (ii) word count of the reflection notes, (iii) number of concepts used in the reflection notes, (iv) number of times the "Investigate more" search engine feature was used, and (v) time spent using the system to take reflection notes and explore through the "Investigate more" feature.

To ensure that the virtual environments used across both study conditions were comparable, we also assessed the degree of presence felt by participants in each condition using the Igroup Presence Questionnaire (IPQ) with a 7-point Likert scale (Schubert et al., 2001).

6. Data analysis and results

Type the main text in 10-point Times New r. Appropriate statistical tests were conducted for all measures. For all the tests, a significance threshold of .05 was considered. Parametric tests were typically used, and in cases where the data was not normally distributed, non-parametric tests were used.

The IPQ (Igroup presence questionnaire) questionnaire's average score was calculated for each participant for both the in-situ and post hoc conditions. A paired sample *t*-test was conducted on IPQ scores. Results showed no significant difference in terms of presence in the virtual environment between in-situ (mean = 3.77, *SD* = 0.69) and post hoc (mean = 3.85, *SD* = 0.69) conditions. Thus, it can be considered that the environments were comparable in presence aspect across conditions. We report on the study results below by research question.

6.1. RQ1: Differences in everyday questions capture

Questions recalled by participants in the Memory Snippet interface were compared to actual questions asked out loud during the study task. Three categories were created for (recall) question comparison as follows: (i) accurate recall – exactly the same question or question with the same meaning and different wording; (ii) partial recall - similar question that is based on the same object or action but different from the original question; (iii) incorrect recall - totally different question from what was asked in the moment, or were left blank because of not being able to recall.

We found that 80.25% of the questions were recalled accurately, 8.64% of the questions were partially correct, and 11.11% were incorrect. Thus, we concluded that people were able to use the contextual cues in the Memory Snippet system to recall their questions correctly sufficiently enough.

The total number of questions asked by a participant in each condition was counted, and the Wilcoxon signed-ranks test was run. Results showed that a significantly higher number of questions were asked in the post hoc condition (mean rank = 14.47) compared to the in-situ condition (mean rank = 11.31), $Z = -2.171$, $p = .03$.

Thematic analysis was done to understand the type of questions people asked in each condition. For this analysis, one researcher read through all the questions and in consultation with another researcher generated the following emergent coding scheme:

- How - questions that seek to understand the process behind something, e.g., "How is electricity provided to the lights outdoors in the grass?";
- Why - questions that seek to understand the reason behind something, e.g., "Why are these plants colored so strangely?";
- Describe - questions whose responses tend to be subjective, such as the information asked for can be both straightforward or involve learning new concepts depending on how one wants to look at it, e.g., "How fast does grass grow?";

- What - questions that require only a short, typically one-word answer (count, year, name, etc.), e.g., “What year was this picture taken?”; and
- Y/N - questions with responses that would be yes or no, e.g., “Is this a stroller?”

A second coder coded 10% of the data using the above coding scheme. After two rounds of discussion, coding, and coding scheme revisions, a high inter-coder agreement was achieved with a kappa value of .84 (Landis & Koch, 1977). The count and percentages (calculated by dividing the number of questions for a question type by the number of all questions asked in that condition) of each question type in each study condition are listed in Figure 7. The post hoc condition had a higher number of questions that inquire about reasons, i.e., “why” questions, whereas the in-situ condition led to more “what” type of questions.

Figure 5. Count of each type of question asked in In-situ and Post hoc condition

In-situ Recall and Reflection			**Post-hoc Recall and Reflection**		
Question Type	Count	Percentage	Question Type	Count	Percentage
Describe	7	4.46%	Describe	7	3.80%
How	42	26.75%	How	47	25.54%
What	56	35.67%	What	48	26.09%
Why	39	24.84%	Why	54	29.35%
Y-N	13	8.28%	Y-N	28	15.22%

6.2. RQ2: Differences in reflection engagement on everyday questions

The number of times reflection notes were taken was calculated for each participant in both conditions, and the Wilcoxon signed-ranks test was run. Results showed that a significantly higher number of times reflection notes were taken in the post hoc condition (mean rank = 14.76) compared to the in-situ condition (mean rank = 7.42); $Z = -3.194$, $p = .001$.

The total word count of all reflections made by each participant was calculated for both conditions, and the Wilcoxon signed-ranks test was run. Results showed a significantly higher word count for reflection notes in the post hoc condition (mean rank = 17.38) compared to the in-situ condition (mean rank = 9.72); $Z = -2.811$, $p = .005$.

To assess the number of concepts embedded in reflection notes, we identified all singular meaning units within the questions asked. For example, in the reflection statement, “It’s not really on fire, just gives a sensation of heat when consumed, akin to heartburn,” 3 concepts were identified: “It’s not really on fire,” “just gives a sensation of heat when consumed,” and “akin to heartburn.” This means unit coding was done by a first coder, and then a second coder coded 10% of the data. After two rounds of discussion and coding, a substantial agreement was achieved with a kappa value of .69 (Landis & Koch, 1977). The number of concepts was then calculated for each note taken. The Wilcoxon signed-ranks test was performed to find any significant difference in the number of concepts used in reflections. The results showed that a significantly higher number of concepts were embedded in reflection notes from the post hoc condition (mean rank = 14.05) compared to the in-situ condition (mean rank = 9.67); $Z = -2.813$, $p = .005$.

Other measures used for engagement in reflection were the number of times a participant used the “Investigate more” feature to continue exploring their question and the average time people spent on reflecting and exploring all their questions. The average time spent reflecting and exploring all the questions in a condition was the period between completing recalling and noting down the question (the participant clicking the save button for the question) and completing the review of the question (the participant clicking of review of moment completed button after exploration using the “Investigate more” feature). Results of Wilcoxon signed-ranks tests showed that participants used the “Investigate more” feature significantly more in the post hoc condition (mean rank = 10.25), compared to the in-situ condition (mean rank = 9.93); $Z = -2.195$, $p = .028$, but that there was no significant difference in the time spent by a participant in reflecting and exploring their questions between the two conditions.

7. Discussion and conclusions

Our results show the potential of the post hoc recall and reflection approach to support everyday question-asking. We observed an increase in exploratory and reflective behavior associated with question-asking in daily life environments when using the post hoc recall and reflection approach, compared to the in-situ approach. Our results showed that the post hoc approach outperformed the in-situ approach in almost all aspects that we analyzed, except for the time spent exploring the question. Even no significant difference in time spent is meaningful for the post hoc approach, which we discuss later. List of all the contributions through the work in this paper is mentioned in Table 2.

Table 2. Study contributions

Exploration	Contributions
Cues for recall	Image cue is reported to be most helpful in supporting recall of a moment
Feasibility of cues for recall	Contextual cues can help most of the times (78%) in post event recall
Recall rate in the study	Post hoc approach for supporting recall through cues, can help most of the time (80%) in recall
Post hoc vs in-situ on the amount of question-asking	Use of the post hoc approach led to users asking significantly more curiosity-based everyday questions than the in-situ approach
Post hoc vs in-situ reflecting on question-asking	Use of the post hoc approach led to users reflecting significantly more on the questions they asked than the in-situ approach
Post hoc vs in-situ on exploring question-asking	Use of the post hoc approach led to users exploring significantly more about the questions they asked than the in-situ approach

Our results show the potential of the post hoc recall and reflection approach to support everyday question-asking. We observed an increase in exploratory and reflective behavior associated with question-asking in daily life environments when using the post hoc recall and reflection approach, compared to the in-situ approach. Our results showed that the post hoc approach outperformed the in-situ approach in almost all aspects that we analyzed, except for the time spent exploring the question. Even no significant difference in time spent is meaningful for the post hoc approach, which we discuss later.

We found that participants asked a higher number of everyday questions in the post hoc condition compared to the in-situ condition. A possible explanation for this is that in the post hoc condition, participants did not have to note down the questions and reflections during exploration, which made them more available and hence more immersed in exploring the environment. This led to keener observation, which led to asking more questions. This shows support for recalling is needed and useful (Brewer et al., 2017). On the other hand, in the in-situ condition, having to switch back and forth between the exploration environment and the interface to note down the question disturbed the flow of the experience, leading to fewer questions asked. The post hoc approach provides support for lifelong learning by being learner centered (Sharples, 2000). Our results thus indicate that the post hoc approach has the potential to better support lifelong learning by encouraging the user to collect and capture more questions from the environments of daily life without disrupting the flow of the everyday task.

In terms of the types of questions asked, the distribution seemed different depending on the condition. In the in-situ condition, the What question type appeared to dominate. What questions are typically associated with what is called "factual knowledge" in Bloom's revised taxonomy (Krathwohl, 2002). Factual knowledge is the basic level of knowledge that a learner needs to possess in a discipline. It is interesting that the What question type was prevalent in the in-situ condition but not so much in the post hoc condition. Asking what questions may actually be more useful when reflection and inquiry are done in the moment of question-asking since the answers obtained may help to deal with the current situation or environment at hand. This suggests that understanding the type of support that the technological tool provides leads users to ask different types of questions. In the post hoc condition, the types of questions asked were more varied. There seemed to be a slight preference for Why questions, but that preference was not as clear as for the What question type in the in-situ condition. Why questions can be said to relate to "conceptual knowledge" in the revised Bloom's taxonomy (Krathwohl, 2002). Conceptual knowledge enables a learner to understand relationships among different elements in a discipline and obtain a mental picture of the larger structures of a topic. It is considered deeper-level knowledge than factual knowledge. Participants were more encouraged to generate Why questions in the post hoc condition, perhaps because they thought that they would have a chance to actually obtain reasonable answers to the questions given that reflection and inquiry were to take place at a later time. This again suggests that in a lifelong learning scenario, the technological support provided may influence questions that users would ask.

Further, the post hoc approach performed significantly better on different measures of reflection engagement. In the post hoc approach, people took more reflection notes, wrote longer notes, and embedded more concepts in their notes compared to the in-situ approach. Better reflection was possible evidently due to the availability of undivided attention, more time, and fewer competing tasks for the task of recall and reflection in the post hoc condition compared to the in-situ condition. What we expected, however, was that based on situated learning theory, the in-situ approach would allow participants to take advantage of their embeddedness in their environment to make their reflections richer. This did not seem to be the case. This suggests that the dedicated time and attention provided in the post hoc approach may be more important than situatedness for lifelong learning engagement. It could also be that users need more support to harness the situatedness of their environments to improve their reflections in an in-situ approach. Examples of additional system support may be automated recognition of objects in the environment, or the provision of reflection structures generated from artificial intelligence techniques. It is also possible that the type of environment used for the study may not be immersive enough for the participants to be fully embedded in the environment. It is also essential to note that immersion in a daily life environment usually happens when one is actively involved with the environment or is intellectually available to reflect in the environment. Future investigations should further conduct this study in a real-life setting to validate the results. Real-life settings might be more immersive and may support more question asking. Nonetheless, the task at hand in real-life is usually important to the user, which may lead to reduced question-asking.

Participants conducted an inquiry into their questions using the "Investigate more feature" significantly more in the post hoc condition, as compared to the in-situ condition. However, there was no significant difference in the average amount of time spent by a person reflecting and exploring their questions. A possible reason for higher exploration in a similar time duration could be greater focus and undivided attention on the task of exploration in the post hoc condition. Also, repeatedly performing the same task of recalling and reflecting on each question one after another may have helped participants know what to look for in their explorations. In the in-situ condition, our observations were that participants appeared to go back to consult the object of questioning more frequently during reflection. The results on reflection engagement seem to suggest that the post hoc approach is more efficient in helping users to pursue their everyday questions.

Overall, based on the study results, we conclude that providing technological support using a post hoc recall and reflection approach supports lifelong learning better than an in-situ approach. Being in the moment (in-situ approach) of question-asking, at least in theory, has the benefit of situated learning, making learning meaningful (Brown et al., 1989; McLellan, 1996) and promoting higher-order thinking (Herrington & Oliver, 1999), but the technological support enabling immediate question capture and exploration does not seem to live up to its stated potential. It seems that despite their situatedness in the actual environment of question-asking, participants were not able to harness the full richness of the context to positively affect their questions and reflections. Yet practically, the in-situ approach of question asking and reflection tends to happen routinely. We see people searching for answers on the web on their smartphones in the middle of a task or a conversation. This also indicates that there is a possibility of combining both in-situ and post hoc approaches to reap the benefits of both approaches. This may result in more reflections than the post hoc approach alone. We propose that technological support approaches more in line with the post hoc recall and reflection approach need to be developed to truly support lifelong learning. By definition, lifelong learning involves learning anytime, anywhere, based on what captures one's interest and attention. Nevertheless, the learning aspect of it does not need to happen "anytime, anywhere." It should be noted that the effectiveness of cues in helping recall in the preliminary study was measured for a day gap between the moment and recall and reflection. It is possible that the effectiveness of the post hoc approach may change if there is a much larger time gap between the moment and recall and reflection. Furthermore, post hoc technological support may span beyond just reflecting once on questions at the end of the day. It can support reflecting, recollecting, and restructuring knowledge recurrently in the future as the system can track and log all reflection activities. While this study investigates a single session of revisiting and reflecting on the moment, such reflection can be longitudinal in nature where users revisit and add to their previous reflections. This will enable persistent learning to support lifelong learning (Sharples, 2000). This type of logging for reflection is also discussed by Sellen and Whittaker (2010). They proposed using lifelogging for capturing specific moments of life with specific details for a dedicated purpose such as exploring, reflecting, and learning. This can support constructive learning by building new knowledge over previous knowledge and reflections. Future research needs to investigate how to design technological support for post hoc approaches that can seamlessly fit into users' everyday lives. An investigation to gather insights into long term user behavior while using technological support for the post hoc approach will help in fathoming the usefulness of this approach to support lifelong learning.

Future investigations can also explore in the direction of using the post hoc approach as an ad hoc support for in-situ exploration. This could potentially help in overcoming the cons of the in situ approach, where the user could explore in the moment if they can, or else they could pursue it later using the post hoc approach. This combination of both approaches may help in long-term learning by keeping logs of all the learning activities with the possibility of revisiting prior reflections and further reflecting and making connections with new items learned. This approach would also be in line with constructivist theory, where one not only keeps acquiring new knowledge but actively making connections and restructuring existing knowledge. This extends in the direction of lifelogging, which focuses on capturing learning moments combined with lifelong learning. To further support lifelong learning, future research should also investigate other factors, such as motivation and drive, which can support curiosity-based exploration and reflections in daily life. Investigation in this direction may even result in more exploration in the in-situ approach. While question-asking may appear as one way to support learning, it is indeed the key. Explorations may lead to inquisitive nature and arousal due to learning gains, which can further stimulate larger learning goals such as learning about a new topic, motivation to acquire a new skill, and learning through online courses.

8. Limitations

We acknowledge that conducting the study in virtual settings due to the COVID-19 pandemic might have limited participants' engagement in a full-fledged environment that provides embodied cues. Virtual environments, at least using current common technologies, prioritize the visual sense. Future work should evidently investigate the two approaches proposed in real-life physical settings. Another limitation could be the time delay between exploring the environment and recall and reflection that was used in this study for the post hoc approach. We had a relatively short time delay filled by survey completion that was used as a distractor task. In practical use of such an approach, the different time delay between the curiosity moment capture and recall could be longer. Future research should investigate what would be appropriate time delays between moment capture and question recall and reflection for the post hoc approach. Future investigating should conduct longitudinal exploration in real-life settings to validate our results and further reveal the benefits of using either of the approaches for lifelong learning.

Acknowledgement

This project was partially supported by NSF grant #1566469 Lived Science Narratives: Meaningful Elementary Science through Wearable Technologies and NSF grant #1942937 Bridging Formal and Everyday Learning through Wearable Technologies: Towards a Connected Learning Paradigm.

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