"I Was There in 1770 Boston"
A Classroom Study of TimeSnap VR

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Introduction

Between December 2019 and February 2020, EDC's Center for Children and Technology conducted a classroom study of *TimeSnap*, a VR interactive created by Electric Funstuff under a Phase II Small Business Innovation Research (SBIR) grant administered by the US Department of Education's Institute for Education Sciences (IES).

TimeSnap supplements traditional history teaching by giving students an immersive VR "deep dive" into a historical period and problem, and giving teachers curricular supports for deepening students' understanding through discussion, writing and further study.

Broadly, the study goal was to determine whether high school students who participate in Time Snap VR-enhanced lessons demonstrate (1) stronger recall of historical content knowledge and (2) greater facility with historical thinking, compared to peers in business-as-usual classes. We also hoped, through interviews and observations with students and teachers, to gain insight into *how* the VR medium, as embodied in the TimeSnap interactive, might offer features and affordances that can support history teaching and learning more broadly.

This report summarizes the major research findings; a fuller version that situates the study in prior theory and research is being prepared for publication.

Materials, Subjects and Methods

Materials

The material studied was a TimeSnap module on the causes of the Boston Massacre.[1] The module included the VR app itself, student worksheets, and a Teacher Guide with suggested discussion questions and activities. The student VR experience was a 20 to 25-minute exploration of events, people, objects and settings surrounding the Boston Massacre of 1770. In the VR experience students work for a fictional future government agency called CARPA and are charged with recovering lost connections between elements of an historical archive that has become fragmented. With an avatar named Director Wells as their guide, players 'Time Snap' back to 1770 Boston shortly after the Boston Massacre has occurred, and explore three locales in search of information about the causes of the massacre: the workshop of patriot artisan Paul

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[1] A parallel module on the Fugitive Slave Law was not studied due to Co-Vid19-related school closures.

Revere, a Boston tavern, and the jail cell of British Army Captain Preston. In each locale, three key VR features give them access to people, objects and documents that offer clues to the massacre's causes, and to competing patriot and loyalist views of the event:

- Players can *mind meld* with historical and fictional characters they encounter, hearing their inner thoughts about their own actions, goals and interpretations of events;

- Players can *pick up and rotate objects* they encounter, such as clothing, artifacts and manuscripts that offer further details and clues;

- Players can *zoom in to details* of key documents, such as Revere's polemical print depicting the 'Bloody Massacre', while Director Wells offers audio guidance in analyzing them.

During their VR explorations, students are asked to pause and reflect on what they are discovering. In doing so they collect 'field notes'—summary statements they deem important to understanding the causes of the massacre, and patriot and loyalist perspectives on it. At mission's end their field notes are emailed to them, so they can bring them into classroom discussions and writing. The Teacher Guide offers guidance in holding classroom discussions, having students share their conclusions about the massacre and its causes, the reasons for believing and disbelieving patriot and loyalist accounts, and the evidence that supports these.

The module's learning goals are threefold:

1. To deepen students' knowledge of the *causes* of the Boston Massacre—in particular, to help them develop a *multicausal*, rather than a *mono-causal*, account of the outbreak of violence;

2. To deepen students' ability to identify and reason about patriot and loyalist *viewpoints* on the events;

3. To deepen students' skill in *analyzing primary documents*—including their ability to *observe details* and identify the *author's viewpoint*

Subjects

TimeSnap was studied in six US history classrooms in four high schools in suburban New Jersey. The schools served relatively affluent and ethnically homogenous student bodies, as shown in Figure 1.[2] In each school, classes chosen for participation were matched as closely as possible based on student ability level and the ratio of ELL and special needs learners. One of the matched classes was then assigned to serve as a treatment class (total N=55), and the other a

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[2] Recruiting a more diverse sample proved challenging. VR is novel and unproven, and by December most teachers had already taught about the Revolutionary Era. As a result, interested teachers came from schools where educators had the confidence and curiosity to embrace pedagogical and technological experimentation with VR as a value in its own right. These tended to be more advantaged schools.

comparison class (total N=46). (Two of the matching classes were in separate, demographically similar high schools.) In total, 101 students participated in the study.

Figure 1[3]: Participating New Jersey High Schools

	Free Lunch	ELA Proficiency	Graduation rate	Diversity Score[4]
School 1	5%	50%	95%	.15
School 2	14%	35%	91%	.22
School 3	2%	57%	96%	.26
School 4	1%	67%	98%	0.19

Procedure

In *TimeSnap* classrooms, teachers administered the Boston Massacre module over 2-3 school days. Prior to the study they received a set of Oculus VR headsets, the VR app, the Teacher's Guide, and a 90-minute in-person PD session on how to use them. A typical teaching scenario followed this sequence: On Day 1 teachers read aloud a short introduction to the VR 'Mission', students put on VR headsets and played the game for 20-25 minutes, and students completed a brief post-VR questionnaire. On Day 2 teachers distributed printouts of students' 'field notes' from the game, and students were asked to identify what they thought were the main causes of the Massacre, and evidence to support their reasoning. Teachers also led class discussions on questions about the causes of the massacre, and Patriot and Loyalist viewpoints on it. Day 3 was sometimes used for additional discussion and extension exercises, such as having students draw a more historically accurate version of what happened in King Street than Paul Revere's engraving.

In comparison classrooms, students worked with a paper-based packet of more traditional Document-Based Questions on the same topic, the Boston Massacre, over 2-3 periods. Teachers presented a brief mini-lecture on the Massacre and its causes, then students analyzed a set of 3 primary source documents using accompanying guiding questions. Once students had completed their packets, the teacher led a whole-class discussion about the Massacre, causes, and different perspectives. Students then completed a performance task, filling out a detective's report on the Boston Massacre and recommending who should be held accountable and why, using evidence from the documents they had analyzed.

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[3] Data collected from publicschoolreview.com June 4th, 2020.
[4] The chance that two students chosen at random would be members of a different ethnic group. Scored from 0 to 1. A score closer to 1 means a more diverse population.

Research Questions and Data Collected

EDC researchers sought to answer three questions:

1. Compared to peers in more traditional classes, do high school students who participate in TimeSnap lessons demonstrate:

   a. Greater gains in *historical knowledge* (i.e. about the causes of the Boston Massacre)?

   b. Greater gains in *historical thinking skills* (i.e., the ability to analyze primary sources, and to identify and reason about different historical viewpoints)?

2. How do students relate to and experience history content in a VR-supplemented lesson?

3. To what extent are teachers able to integrate students' experiences in VR with the associated classroom activities successfully to achieve the learning objectives? What modifications does the teacher make to the lesson activities or curriculum materials, and why?

To answer Q1 researchers administered a pre/post measure of historical knowledge and skills to both TimeSnap and Comparison classrooms. The measure included 5 content knowledge items about the Boston Massacre and its antecedents, 5 items that addressed historical thinking concepts and skills, and a document analysis task (post-test only). (See Appendix A)

To answer Q2 researchers observed TimeSnap lessons, administered a post-VR survey, and interviewed subsets of students after the lessons. (See Appendix B)

To answer Q3 researchers observed TimeSnap lessons and interviewed teachers after the lessons.

Results

1. Gains in Historical Knowledge and Skills

Students in *TimeSnap* classrooms showed significant gains in historical knowledge, concepts and skills compared to their peers who studied the Boston Massacre via traditional paper-based methods. Specifically, three gains are discussed below:

- TimeSnap students showed statistically greater gains in *historical knowledge of the Boston Massacre*, compared to peers in traditional classrooms

- TimeSnap students showed greater grasp of two key concepts—*historical causation*, and *historical perspective*—than peers in traditional classrooms

- After using TimeSnap, students displayed stronger *document analysis skills* when confronted with a novel visual source, particularly in *observing visual details*, and identifying the *author's viewpoint*.

1.1 Historical knowledge of the Boston Massacre

The TimeSnap group showed significantly greater change on a 5-item measure of historical knowledge of the Boston Massacre than did the comparison group. All students were administered 5 historical knowledge items (See Figure 2 below) before and after the intervention. A difference of means analysis was performed on the scores (one-sample t-tests of pre-post change scores).

 2 shows that the TimeSnap group saw statistically significant pre-post change on items 2, 3, 4 and 5. No statistically significant pre-post change emerged for the comparison group.The mean change score for the TimeSnap group was .19 compared to .04 for the comparison group (t=-2.7, p<.01). The Cohen's d value is .54, which indicates a medium effect size.

Figure 2: TimeSnap Students' Improvement on Knowledge Items. Historical knowledge items that show significant pre-post change, Treatment group (n=56)
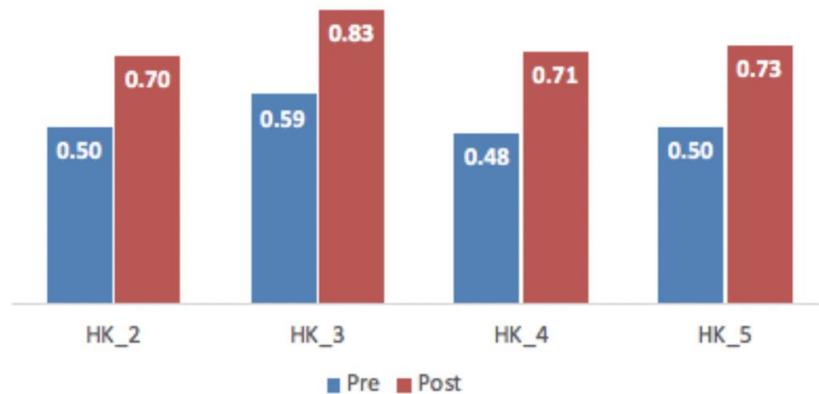
Examining the 4 knowledge items on which TimeSnap students improved significantly (see Figure 3 below), we see that students gain most on knowledge that is connected to the key concepts that the *TimeSnap* app targeted—multi-causality, historical perspective, and the interpretation of source documents.:
- The *multiple causes* of the Boston Massacre (Items 2 and 3)
- *Anti-British sentiment* and organizing (Item 4)
- The *rhetorical role of a primary document* (Item 5).

Students did not improve on Item 1, involving a basic definition of the Boston Massacre, likely because they already scored high on this question in the pretest.

Figure 3: Pre/Post Historical Knowledge Items on the Boston Massacre

1) The Boston Massacre is best characterized as
   a) the public execution of several prominent revolutionaries
   b) the deadliest battle of the American Revolution
   c) an attack on a British tax collector by the Sons of Liberty
   d) the shooting of Boston civilians by British troops during a riot

2) Which of the following events helped cause the Boston Massacre? Choose as many as you think apply.
   a) The Townshend Acts
   b) The presence of British soldiers in Boston
   c) The Boston Tea Party
   d) Conflict between soldiers and ropewalk workers
   e) The Intolerable Acts
   f) Resistance to British rule by armed militias

3) All of the following are true of the Townshend Acts EXCEPT
   a) The Acts were passed in response to the Boston Massacre
   b) The Acts included new taxes on imported goods like tea and glass
   c) The Acts attempted to generate revenue for the British administration in the colonies
   d) The Acts were so unpopular that British troops were sent to Boston to assist enforcement

4) The Sons of Liberty were an example of
   a) Puritan clergymen angry about British power in Boston
   b) secret anti-tax organizing in the colonies
   c) Aristocrats controlling colonial government
   d) Loyalist sentiment in wartime New England

5) Which of the following was a significant consequence of the Boston Massacre?
   a) The end of hostilities between Loyalists and Patriots
   b) The spread of anti-British feeling through Paul Revere's engraving
   c) The passage of the Intolerable Acts
   d) The repeal of the Townshend Acts

## 1.2 Grasp of Historical Thinking: Multicausality & Historical Perspective

In addition to content knowledge, TimeSnap students showed significant improvement on two pre-post items measuring historical thinking. Comparison students showed no improvement on these items. Figure 4 below shows pre-post changes in the number of TimeSnap students who agreed or disagreed with two statements:

- Q1: Important events in history typically have a single cause.

- Q4: When eye-witnesses see the same event, they generally agree on what happened.

Before using TimeSnap, students were more likely to *agree* with Q1, saying that historical events tend to have a single cause. After TimeSnap, students were more likely to *disagree* with the statement—suggesting they now had a more multi-causal view of historical events.

Similarly, before using TimeSnap students were more likely to agree that "when eyewitnesses see the same event, they tend to agree on what happened," while afterward more of them disagreed with this statement (Q4). These data are consistent with the idea that using TimeSnap gave students a deeper appreciation of the different viewpoints and perspectives that people, including eyewitnesses, bring to historical events.
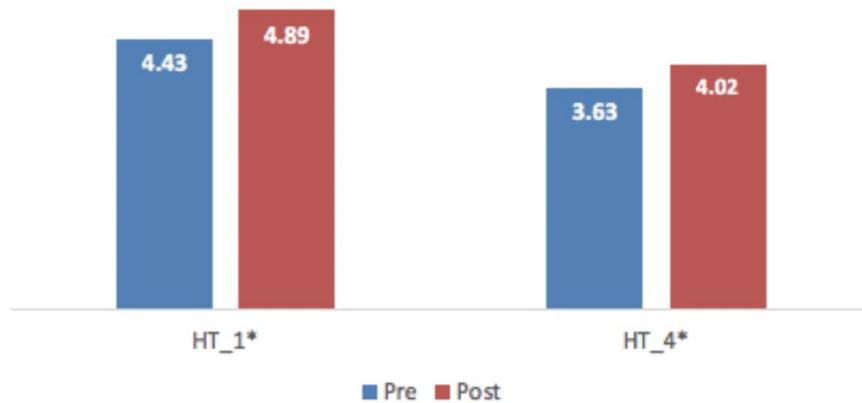
1.3 Stronger Document Analysis Skills

Finally, TimeSnap students out-performed comparison students on a document analysis task, in ways that suggest the VR app and classroom lessons may be effective in building student document analysis skills such as closely observing details, and using these details to infer the author's viewpoint or perspective.

Post-test Document Analysis Task. The post-test asked all students to analyze the following version of a 1774 engraving, *Bostonians Paying The Excise Man, or Tarring and Feathering.* Students responded to prompts that asked them to:

- Observe the document and note important details (free note-taking)

- Identify who the author felt sympathy toward—the colonial protesters or the tax collector (multiple choice)

- Indicate whether the print represents a Patriot or a Loyalist perspective on colonial protest (multiple choice)

- Explain and support their analysis using reasoning and evidence (free note-taking)

Figure 5: Bostonians Paying the Excise Man, or Tarring and Feathering

Researchers analyzed and coded student responses on each element of the task. Figure 6 presents a summary of student performance.

Figure 6: Student Performance on a Post-Test Document Analysis Task

	TimeSnap Students (N = 57)		Comparison Students (N=45)	
Elaborated Observation	26	45.6 %	8	18 %
Author Sympathies Identified	43	75.4 %	31	68.8 %
Loyalist Perspective Identified	41	73.2 %	27	60 %
Cogent, Supported Interpretation	38	69 %	23	51.1 %
Consistent Viewpoint	51	89.4 %	33	73.3 %

As summarized in Figure 6, TimeSnap students performed better than comparison students on all four main elements of the document analysis task—observing visual details, identifying the author's sympathies, interpreting the author's perspective on colonial protests, and linking the details together in a cogent, well-supported interpretation of the author's motives.

A. Document Observation Skills

TimeSnap students outperformed comparison students most dramatically in the observation portion of the task. 45% of Timesnap students produced an 'elaborated observation'—meaning they noted four or more significant details in the image, and often connected these in sentences. By contrast, only 18% of the Comparison students produced elaborated observations. Figure 7 presents examples of the two kinds of observations.

Figure 7: Examples of Student Document Observations

Elaborated Observations (4 or more details noted)	Limited Observations (3 or fewer details noted)
I notice there is a rope hanging from the tree. I also notice that the other people are wearing colored clothing while the man being attacked is wearing white. I notice one of the men is carrying a club so he is most likely a rope-maker. This means that the men in colored clothing are most likely colonists and the white-clothed man is most likely British. I notice the men are trying to get the man to drink something. I also notice they are by a bay with a ship in the background, they are most likely in Boston.	They're torturing a guy by putting tea in his mouth.
• Tarring and feathering a tax collector • Colonists are doing it • The tree says Liberty Tree and there is a rope for hanging • People are dumping tea in the background off a boat (Boston Tea Party)	• Tarring/feathering the tax collector • Liberty tree has a rope hanging from it that was used to hang people

B. Identifying the Author's Perspective

TimeSnap students were also more adept than comparison students at identifying the engraving creator's sympathies, and their overall perspective on colonial protest. Asked whether the creator's sympathies lie with the tax collector or the colonists, 75% of TimeSnap students correctly identified the tax collector—who is shown being tarred and feathered and having tea forced down his throat—as the object of sympathy, compared to 69% of Comparison students. More striking, nearly three quarters of TimeSnap students (73%) correctly saw the engraving as representing a Loyalist perspective on colonial protests—that is, a critique of Patriot villainy and excesses—while only 60% of Comparison students did so.

C. Producing a Cogent, Well-supported Interpretation of the Author's Motives

Finally, TimeSnap students were more likely to produce a cogent, well-supported analysis of the engraving, tying together details in a coherent overall interpretation of the author's motives in creating it. 69% of TimeSnap students produced these, while 51% of Comparison students did so. Figure 8 presents examples of the two kinds of interpretations.

Figure 8: Examples of Student Document Interpretations

Cogent Analyses	Mis-Readings
I think the image represents a Loyalist Perspective on colonial protests because the creator is displaying how violent the colonists are behaving. I think the creator felt sympathy for the tax collector because he is being attacked and none of the colonists are helping him. I know this because there are ships in the background and nobody is helping.	I see this image as the Brits harassing the colonists and forcing them to do things that they don't want to and hanging them if they don't follow the rules. The picture has a red coat in front of a noose.
The image is obviously made to make the colonists look bad, they even have an evil look on there (sic) faces. It looks like they are torturing an innocent man.	I think it is a patriot perspective because it shows a tax collector being tortured and other colonists in the background dumping tea.
The image is from a loyalist perspective since it's making the colonists seem happy that they are torturing the man and even shows the Boston tea party in the back which correlates to the torturing of the tax collector.	The image uses a Patriots perspective and it shows the Patriots were more innocent.

Improved Historical Thinking: Additional Evidence

Additional qualitative data we collected supports conclusions drawn from the pre/post data. In particular, TimeSnap student writing reinforces the conclusion that many students developed a multi-causal account of outbreak of violence (comprising British acts of taxation and occupation, skirmishes such as the ropewalk fight, and colonial crowd actions) as well as the ability to grasp both British and colonial perspectives on it.

For example, when asked in the post-test to briefly describe what they knew about the Boston Massacre, nearly half of students' open-ended responses (27 of 56, or 48%) reflected a *multi-causal* [mc] and/or a *multi-perspectival* [mp] understanding of the event. Examples follow.

> The Boston Massacre was due to rising tension between the colonists and British soldiers. Many events including the Townshend Acts, the ropewalk fight, and the increased British military presence angered the colonists. **[mc]** Soldiers were also angered by the colonists disrespect and fighting.**[mp]** This ultimately led to the killing and wounding of colonists in Boston.

> It was caused by both the colonists and the British **[mp]**, because tensions were so high—heavy taxation, Townshend Acts, and increased British military occupation. **[mc]**

> Both parties that fought during the Boston Massacre were at fault. The British angered the colonists with taxes and taking over Boston, and the colonists angered the British by calling them names and starting riots. **[mp, mc]**

> The colonists got very angry with the British soldiers who were in their homeland, and combined with their anger against taxes, attacked the soldiers that were there.**[mc]** In response, the British defended themselves best as they could and ended up killing a few people.**[mp]**

> Britain had sent over 1,000 men to Boston to regulate trade and taxation. The way that the men carried themselves around town made the colonists feel like they were in a foreign land, this caused tension between the colonists and the men.**[mc]** Things such as press and riots accrued which led to the open fire of British men. CARPA has helped me understand the different points of view of the massacre and what led up to it.**[mp]**

2. Students' Experience of the TimeSnap VR Design

To what extent, and in what ways, were the features and design of TimeSnap VR responsible for the student gains documented in the study? As this section documents, students enjoyed their TimeSnap mission, and said it helped them learn history in ways traditional reading and lectures did not. Yet it is almost certain that the VR experience alone is not responsible for the measured gains. The app was designed and used as part of a larger classroom experience, as the "experiential core" around which classroom discussion and writing occurred. It is also more than likely that teacher variables—history teaching experience, skill and enthusiasm—played a role as well, since this was a small study without true randomization by teacher and classroom.

This said, taken together, questionnaire and interview data support the conclusion that **the TimeSnap design succeeds in exploiting the features of VR in ways that support engaged history learning**, in particular the development of **historical empathy and perspective-taking**. In support of this claim, we first present data to support two sub-claims.

2.1 Students said they enjoyed TimeSnap and felt the VR format helped them learn.

As indicated in Figure 9, students found the VR medium appealing, and that they felt specific features like the 'mind melds' were effective at giving them access to characters' differing perspectives.

Figure 9: Student Survey Responses who agreed or strongly agreed with the following statements about the TimeSnap VR interactive (n=60)

Statement	Percentage who "Agreed" or "Strongly Agreed"
I enjoyed learning about history through VR.	82%
Hearing different people in the tavern helped me see that the *Colonists and the British had different perspectives on the conflict.*	82%
Listening to Paul Revere think about his engraving of the Boston Massacre helped me understand *the image's anti-British perspective.*	78%
The VR environment helped me *remember the historical content* better than a video or a book.	68%
The VR experience *helped me understand the documents I analyzed* in the lesson.	65%

2.2 Students found several TimeSnap features most salient—all features that were specifically designed to advance historical understanding of the massacre's causes, and clashing perspectives on it

When students were asked in a post-VR questionnaire what they remembered most about the TimeSnap experience, they responded through open-ended writing. Figure 10 shows the features they discussed most. Interview data reinforced this list.

Figure 10: Salient Features of TimeSnap for Students (n=56)

Feature	Salience	Associated Skills
Mind-Melds with Characters	20 mentions	Identify historical perspective
Really Being There (Presence)	12 mentions	Historical empathy
Interacting with Objects & Documents	10 mentions	Close Reading, Contextualization, Multi-causal explanation
Audio Elements, incl Director Wells	8 mentions	Sourcing, Corroboration

A. Mind Melds: Hearing Historical Figures' Thoughts

The design feature that students said stood out most for them was the Mind Meld, in which players clicked on a historical character to 'overhear' his or her thoughts, rendered in spoken audio, as well as an optional transcript. Student comments make clear that this feature played an important role in helping them understand the differing viewpoints of key historical figures—especially Paul Revere and Captain Preston, on opposite sides of the conflict:

> I remember mind-melding into important characters at that time, like Paul Revere and Preston, to get two different points of view.

> I remember the mind-mending [sic] feature, where you can go inside of someone's mind and listen to what they were saying. The voices helped me remember who said what things and what was believed between townspeople.

> Mind melding with people is what sticks out. I remember being in the tavern and listening to the ropewalk fight conversation between the two men...

> I remember listening in on people's thoughts. I thought it was cool that we could do that.

> What I recall most is being able to listen to their individual thoughts, as well as find pieces of evidence that corresponded with the person it was found with.

> I thought that the people were very realistic like I could almost talk to them... I very vividly remember that Preston believed he was innocent, and that Paul Revere made it seem otherwise.

While mind melds are an important feature that students used to build historical understanding, students encounter them alongside other features—interactions with objects and documents, and historical information and modeling from Director Wells. It is students' movement between and among these features that helps them build deeper, more contextual understanding. For example, the following student describes how a mind meld with Paul Revere helped her grasp the colonists' emotions toward the British, which when combined with contextual information about troop landings, gave her a sense of "all the tension the colonists felt," and prepared her to understand the Revere print of the massacre. It is a vivid description of how the elements of TimeSnap work together to build student historical understanding:

> I remember [Revere] talking about how the Sons of Liberty were angry with the Townshend Acts and taxation. Then after mind melding with Revere, then I learned about the landing print and the troops landing in Boston, and it just made me think about all the tension the colonists felt that the British were causing to them and their city, so I think it helped me interpret the stuff before I got to the main Paul Revere print.

B. Presence: "Being There" in 1770s Boston

Immersiveness is the characteristic feature of VR, and its subjective correlate, 'presence', is the psychological sense of being 'in' the virtual environment (Slater, 1997). In their open-ended responses students cited presence, or the sense of 'being in Boston in the 1770s', as the second most salient aspect of the TimeSnap experience for them:

> What I remember most about playing TimeSnap was the feeling of being in Boston in the 1700s.

> I remember how real everything looked while I was using the VR set. I was kind of scared when I saw Paul Revere at first, cause he looked so real, and it was like he had just appeared in front of me.

> The graphics were really good, and they made me feel like I was there with Paul Revere and everyone else there in 1770 Boston.

> The thing I remember most was the graphics—how real it all felt.

Students frequently commented on how the sense of physical presence was an aid to memory and recall:

> I felt like I was actually there in Boston, and it caused me to remember specific details. For example, it became easy to remember that Revere was a silversmith, for I was in his workshop. And I can easily remember that Preston wrote a letter to Britain while he was in jail, for I was there with him.

> I remember how real it all looked, and it made me remember information more.

> I remember feeling like I was in Boston, and seeing different important places... that helped show the causes of the Boston Massacre.

C. Interacting with Objects

TimeSnap deploys the features of VR in the service of building students' disciplinary skill—the skills of sourcing, contextualization and corroboration that historians routinely practice in analyzing artifacts and primary documents (Wineburg, 2001). Students cited two features in particular—the ability to pick up, rotate, and 'zoom into' objects and documents, and the audio guidance of Director Wells—as memorable aspects of the experience that helped them understand the historical context of the massacre.

> What I remember most ...is being able to interact closely with evidence. This includes really cool features like being able to rotate objects or clicking on the blue circle to focus on a specific part of a document like Revere's image.

> The thing that sticks out to me the most was being able to examine and analyze different objects that were crucial to identifying the causes of the Boston Massacre. It was most memorable to be able to understand the biases held about the Massacre through looking at different documents firsthand.

> I remember examining the bowl, the barrel, and the picture of the Boston Massacre.

> I remember…the specific objects being used, for example the written bowl and copper plate from Paul Revere's workshop.

> [Zooming in on documents] really helped me comprehend the documents and evidence better than I had previously when we learned it in class by simply looking at it on paper and talking about it.

> I remember most being able to rotate the objects to see different parts of it. I also remember most being able to look closely at Revere's painting and being able to see small details that I hadn't noticed before.

Given that students themselves say that the haptic and zoom-in features of TimeSnap helped them closely examine documents, we can conjecture that these features helped contribute to their stronger document analysis skills. Closely connected to this was the audio guidance of Director Wells.

D. Audio Elements, Including Director Wells

Audio was also a salient part of the TimeSnap experience for students. In their open-ended responses they called out three audio features in particular: Director Wells' audio guidance, the location-changing sound effect, and the voice actors' readings of documents.

Director Wells plays several important roles in TimeSnap: giving players their mission, providing contextual information about the massacre, and helping to guide and model document-reading, by reinforcing authorship (sourcing), calling out details (close reading), and pointing out discrepancies (corroboration). Students noticed Wells' role and said it was helpful:

> I remember there was an instructor telling us what to do and where we would go based on our responses.

> Having the narrator give us clues as we examined things was good.

Ambient sounds were also noted by students, as well as game sound effects, in particular the electronic 'whoosh' that accompanied movement to a new time/location:

> I remember the location change sounds—that was cool.

> The sound when you go to a new place was awesome.

Finally, students noted that having actors' read aloud the documents was helpful, especially if as readers in this environment they had trouble focusing. Some also noticed when, because they were playing an early version of the game, one character had a computer voice that stood out:

> It was really helpful to have everything about the document read to you, because often-times when I look at the words in old English I'm more focused about reading it rather than comprehending the impact of it.

> When it was just a computer voice it was weird, I didn't like it.

Altogether then, data on students' experience of TimeSnap supports the hypothesis that a handful of VR features—mind melds, the sense of social presence, interactions with objects, and audio guidance from Director Wells—contributed substantially to the improvement of students' history knowledge and skill.

3. Teachers Response to TimeSnap VR

To what extent were teachers able to integrate students' experiences in VR with the associated classroom activities successfully to achieve the learning objectives? What modifications did they make to the materials?

Researchers analyzed observational and interview data to arrive at several conclusions.

3.1 Teachers generally felt confident about using TimeSnap in the classroom

All teachers reported feeling confident that they could incorporate TimeSnap and the related curricular materials into their classroom. Teachers felt that students reacted well to the content and the medium, and that the VR experience tied into the lesson well.

> It was completely different than anything I had done. I did not expect the interactive to be as lifelike and it worked very well with the material. Everything was there that was needed for the students to be able to grasp the content and accomplish the mission.

> My students have already worked on point of view this year—or, they've really struggled with point of view. But with the virtual reality, they were definitely better able to understand potential for bias without me having to prompt them or ask specific questions. They truly demonstrated both skill and content mastery with this on a higher level than they typically do.

3.2 Teachers were concerned about the possibility of glitches with VR technology

While teachers found the experience with VR generally smooth, some also noted that there were minor technology issues, such as students getting stuck at certain points in the interactive. All three teachers either noted the need for tech support or shared a concern that if they were to use

VR themselves in the future they might encounter problems that would either take up class time or that they wouldn't be able to solve.

> The technology aspect of making sure that everything's running smoothly is a potential issue. You have to adjust on the fly, but if the kids are hyped and excited about VR then it doesn't work out well, then it's a bummer for them.

> Because VR is a newer technology—it certainly is for me—if there were some kind of glitch, I'm not sure I would be able to solve it in the class.

3.3 Teachers were concerned about the time the lessons took given the narrow scope of content

Teachers also noted that in using TimeSnap they were spending more time on a topic like the Boston Massacre than they typically would. One teacher felt this would be an issue, and wished that the interactives might address larger topics. The other two teachers noted that they couldn't always justify the extra time required, but said that it helped that students were getting important experiences working with historical thinking skills.

> I don't mind spending a little more time on a specific area of the content as long as skills are being utilized. A lot of the focus in education right now is not so much on the volume of the curriculum, but on helping students develop skills, such as investigative skills, critical thinking skills, or things of that nature. I couldn't incorporate it all of the time though, because it would take away from the curriculum that we need to get through.

> While it is an amazing student learning opportunity, it is also time consuming—this is further exacerbated by the idea that this lesson was a singular event in a long list of transgressions during the imperial tax program. It was well developed regarding both skill, content, and questioning, but may not always be practical. It would be interesting to see lessons cover larger concepts.

> I realize that these lessons are in the "testing phase," but having to commit 3 or more days to the lesson is inconvenient with our 43 minute periods.

3.4 Teachers integrated students' VR experiences into classroom teaching via discussion and learning activities

In classroom observations we noted that teachers integrated the VR experience into the classroom in several ways. They asked students to describe characters they met and discuss these characters' perspectives on the Boston Massacre; they asked students to recall evidence about the causes of the Boston massacre from primary source documents they encountered; and they had students use the field notes students generated during their VR experience to support arguments they were making about the causes of the Boston Massacre.

> **Teacher**: When you guys were going through the VR, what emotions do you remember Revere having? What are some of the things that were illustrated?
> **Student**: You hear what he's thinking so it personifies his ange
> **Student**: He was determined

> **Teacher**: Let's list some of the different things you saw in the VR
> **Student**: Captain Preston was in jail. You had to listen to his thoughts.
> **Student**: But you couldn't listen to his thoughts when he's unconscious
> **Student**: The ropewalk fight
> **Student**: I didn't see that
> **Student**: they talked about it in the tavern

3.5 Teachers used the VR experience to highlight conflicting perspectives on the Boston Massacre

During classroom discussions and throughout the lesson, teachers prompted students to share information they learned about the different perspectives on the Boston Massacre, its causes, and who was to blame. These discussions were generally whole-class and featured quick responses between students and teacher rather than deeper student to student discussions. While most conversations focused on the contrasting perspectives of Captain Preston and Paul Revere, there were also discussions of other colonists, and the range of perspectives they had about the British and where blame lay.

> **Teacher**: How about Captain Preston, what do we know about him?
> **Student**: He was in charge of the British soldiers
> **Teacher**: What happened to him?
> **Student:** He got put in jail
> **Teacher**: What were the feelings about him being in prison?
> **Student**: He felt that he was innocent—that he didn't deserve to be in prison.
> **Teacher**: Did you feel bad for him? [⅓ of the class says yes]. If you were Paul Revere, or a Patriot, you're never going to promote the human element of Preston. You saw a different perspective though—maybe he was just doing his job. Historically he's being portrayed as a monster.

> **Teacher**: Did everybody hate the soldiers in the town?
> **Student**: There was that one guy in the tavern who didn't hate the soldiers
> **Student**: The tavern customers all had different points of view

3.6 Teachers didn't always help students evaluate conflicting sources and evidence

Teachers were generally skilled at guiding conversations about Revere and Preston's different perspectives on the massacre, and about the ways in which Paul Revere's engravings exhibited a Patriot perspective and might be considered propaganda. In this way they reinforced what students had been encountering in the VR app about sourcing and contextualizing documents.

At the same time, when students were reading Captain Preston's letter (which protested his innocence) teachers did not press them to consider its trustworthiness in a parallel way, for example that he might have other motivations than truth for pleading his innocence.

In addition, teachers didn't always help students develop strategies to evaluate the conflicting perspectives they found. In the post-VR questionnaire, while half of students had a multi-causal view of the violence and could see both perspective, many of the remaining students simply concluded that 'it's controversial', that 'no one knows what really happened' and that it is essentially a case of 'he said / she said.'

> From playing Timesnap VR, I learned there can be many possible causes for the Boston Massacre, but it's hard to choose who to believe because the British were only looking out for the British and the Americans were only looking out for Americans. I believe Paul Revere may have made the Boston Massacre look more brutal than it was in his engraving in order to earn more Patriot support.

> The British soldiers believe they are innocent, but so do the colonists.

> British believed colonists egged it on Colonists believe British shot first then they were peaceful

3.7 Teachers were able to teach the module without major modifications

Teachers reported in interviews that the lessons and curriculum materials were easy to integrate and that while they may have rephrased discussion prompts into their own words, they generally followed what was written.

> I made some minor changes to wording of some of the tasks.

> I tried to be as authentic as possible to the script provided. I did not want to create a lesson that would alter the data that your company was collected for this experience.

> As described above, I followed the lesson and all the activities, but phrased some of the wording in my own way or in a way that best suited the needs of the students in the particular class. In some instances, I asked follow-up questions to certain student responses to reinforce previously learning historical thinking skills.

Classroom observations confirmed that teachers generally followed what was written in the lessons, although some teachers spent less time focused specifically discussing conflicting evidence or points upon which Preston and Revere agreed.

Several students had minor struggles understanding the directions of how to use the Field Notes worksheet, with some wondering whether they were supposed to be writing about categories of causes—such as taxation—or specific events that might have contributed to the Boston Massacre—such as when ninety-two Massachusetts representatives denounced the Townshend Acts in 1768.

Conclusions and Implications

What are the implications of this TimeSnap classroom study for the design of VR learning interactives, especially in history? We end with several preliminary observations that will be further developed, and related to the emerging literature on VR as a learning medium, in an article in preparation.

VR as Medium for History Learning

The experience of presence—feeling "there" both perceptually and emotionally—helped students develop a deeper understanding of historical perspectives

By experiencing historical information via immersive VR, students were able to connect emotionally to things like the defeat in Captain Preston's voice as he's writing a letter to British officials. This is significant in that historical empathy is a 'cognitive-affective' construct, according to researchers (Endicott & Brooks, 2013).

In TimeSnap, the VR medium helped students build layered contextual knowledge as well as awareness of human perspective—both of which are key to historical empathy (Endicott & Brooks, 2013)

When students 'mind-melded' with Captain Preston they discovered not only that he felt he was innocent of instigating violence, but that he was also angry at the Crown—that he was defending his men in a situation that the Crown had sent them into, and where their presence could not help but upset many Colonists. Preston asks the Crown: What else would you expect to happen? Again, understanding emotions becomes a key to developing a more nuanced historical interpretation.

Building empathy toward historical actors via VR may help prepare students to practice empathy in relation to actors in present day social conflicts

Prior to the TimeSnap module, students knew mainly about Paul Revere, and had either a vague or strong feeling that Captain Preston and his soldiers were "the enemy," responsible for the violence on King Street. Most left the experience believing that the colonists were at least in part to blame, and moreover, understood the experience of both sides in human and contextual terms. Such shifts in perspective are difficult for students—or indeed any citizens—to achieve, and they are especially critical now in a highly polarized political climate. TimeSnap VR and similar history-based interactives may be especially useful aids to the development of civic as well as historical empathy, since they create a historical laboratory for exploring human motives, a structured experience that workshops the process of changing one's perspective as a result of new—and contradictory—evidence.

A cautionary caveat: VR and historical evidence

While VR features helped TimeSnap players feel they were 'really there' in Boston, hearing the thoughts of Paul Revere and Captain Preston, and picking up objects in their rooms, students were, of course, dealing with highly constructed and mediated representations. Yet while students certainly knew they were entering a constructed world, they were not well-equipped to think about and decide what in that world was based on clear historical evidence (the documents, e.g.), what was historical inference (the look of the rooms, e.g.) and what was speculation and dramatic license, though rooted in what's generally known from sources (the mind meld audio of characters 'thoughts').

When asked in interviews if they could trust the information in the 'mind melds,' for example, and why, students differed. Some said yes, they could trust it, because it was what people had actually said; these students assumed that the audio was somehow a historical transcript. Others said they could trust it because, though the exact words might have been made up, they were created by experts who knew the kinds of things the historical figures would probably say. Asked why they thought it was made by experts in history, students replied "Well, we're using it in school."

The caution, of course, is that as the VR medium makes its way into the history classroom, both teachers and students need to learn and practice a VR version of what has been called 'simulation literacy'—the ability parse a technological experience and hold the parts up to scrutiny according to clear truth criteria (Grush, 2011).

This caution is especially apt insofar as we noted that students using TimeSnap were quick to interpret historical figures' emotions, likely due to dramatic audio cues as well as the VR immersion in visually realistic settings. This emotional component can obviously be manipulated. Researchers and writers on historical empathy are careful to stress that it is not primarily an emotional task, and does not, for example, entail imagining "how you would feel if you were that person" (Barton & Levatsik, 2004). Clearly more research is needed on how learners interpret highly immersive historical environments and bring critical thinking about evidence to bear in their interpretations.

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Appendix A: Pre/Post Assessment

Pre- and Post-Assessment Questions

Historical content questions (Treatment and Comparison)

1) The Boston Massacre is best characterized as
   a) the public execution of several prominent revolutionaries
   b) the deadliest battle of the American Revolution
   c) an attack on a British tax collector by the Sons of Liberty
   d) the shooting of Boston civilians by British troops during a riot

2) Which of the following events helped cause the Boston Massacre? Choose as many as you think apply.
   a) The Townshend Acts
   b) The presence of British soldiers in Boston
   c) The Boston Tea Party
   d) Conflict between soldiers and ropewalk workers
   e) The Intolerable Acts
   f) Resistance to British rule by armed militias

3) All of the following are true of the Townshend Acts EXCEPT
   a) The Acts were passed in response to the Boston Massacre
   b) The Acts included new taxes on imported goods like tea and glass
   c) The Acts attempted to generate revenue for the British administration in the colonies
   d) The Acts were so unpopular that British troops were sent to Boston to assist enforcement

4) The Sons of Liberty were an example of
   a) Puritan clergymen angry about British power in Boston
   b) secret anti-tax organizing in the colonies
   c) Aristocrats controlling colonial government
   d) Loyalist sentiment in wartime New England

5) Which of the following was a significant consequence of the Boston Massacre?
   a) The end of hostilities between Loyalists and Patriots
   b) The spread of anti-British feeling through Paul Revere's engraving
   c) The passage of the Intolerable Acts

d) The repeal of the Townshend Acts

Historical thinking questions (Treatment and Comparison)

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
Important events in history typically have a single cause.	○	○	○	○
Important events in history are too complex to be understood by people who didn't live through them.	○	○	○	○
Historians often write about history based on incomplete or missing information.	○	○	○	○
When eye-witnesses see the same event, they generally agree on what happened.	○	○	○	○
Historians know exactly what happened in the past.	○	○	○	○
Historical events change things immediately, not over the long term.	○	○	○	○

Post-Assessment Only Questions

Document Analysis (Treatment and Comparison)

Observation
Closely observe the image below. **Briefly list the details** you think are important.
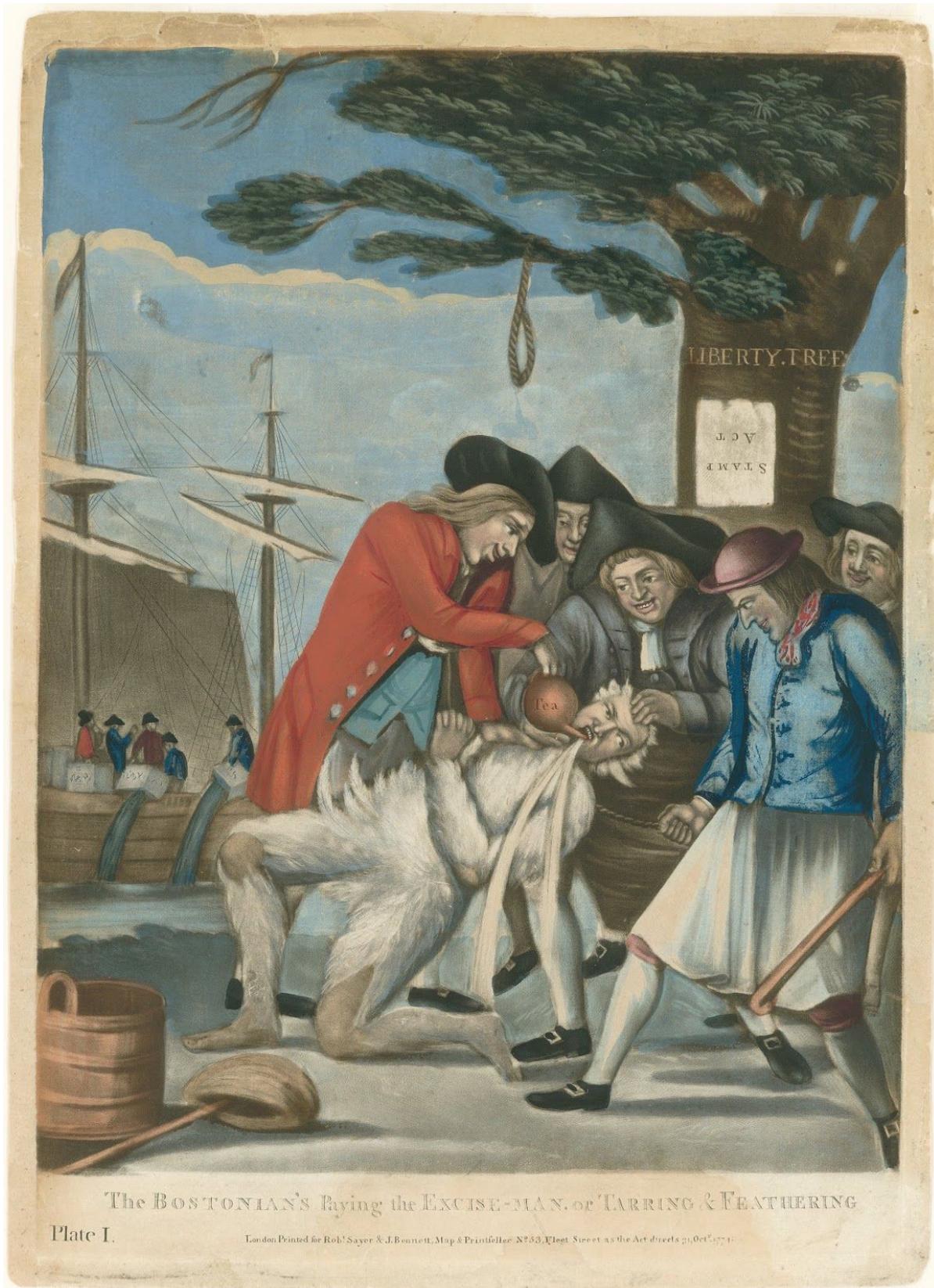
Bostonians Paying the Excise-Man or Tarring and Feathering
London: Printed for Rob't Sayer & J. Bennett, Map & PrintSeller, No. 53 Fleet Street, 31 Oct, 1774

Inference

What do you think is going on — who are the people, what are they doing, and why?

Interpretation

Think about the person who created the image. Who do you think the creator felt more sympathy for?

> ➢ The colonists, who were being taxed by Britain
> ➢ The tax collector, who was being tarred and feathered

Does the image represent a Patriot Perspective or a Loyalist Perspective on colonial protests?

> ➢ A Patriot Perspective
> ➢ A Loyalist Perspective

Explain your responses

Use details from the image and reasoning to support your answer.

Post-lesson VR Experience questions (Treatment Only)

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
I enjoyed learning about history through VR	O	O	O	O
The VR environment helped me remember the historical content better than a video or a book.	O	O	O	O
I felt the VR experience helped me understand the documents I analyzed in the lesson.	O	O	O	O
Listening to Paul Revere think about his engraving of the Boston Massacre helped me understand the image's anti-British perspective.	O	O	O	O
Listening to Captain Preston made me wonder if colonists' stories about him giving the command to "Fire!" were really accurate.	O	O	O	O

Hearing different people in the tavern helped me see that the colonists had different perspectives on the conflict between Crown and Colony.	○	○	○	○

Open ended questions

What do you remember most about playing TimeSnap?

Is there anything about the Boston Massacre, or what caused it, that sticks out in your mind?

Appendix B: Time Snap Post VR-Survey

Thanks for participating in the Mission US: Timesnap study!

We'd like to ask you some questions related to the VR experience you just had. You don't have to answer any questions if you don't want to! And, if you start answering questions, you can stop any time you want. You can also skip any questions you don't want to answer.

Your teachers won't see your answers, and you won't be graded on your answers. This survey is only being used by researchers to find out how students experience and learn from this VR technology.

Name: _____

Teacher's Name: _____

School's Name: _____

Date: _____

Sex:

❏ Male

❏ Female

❏ Non-binary

❏ I'd prefer not to answer

1. **Check off any of the things you might be feeling *as a result* of using the VR headsets:**

	None	Slight	Moderate	Severe
General discomfort	◯	◯	◯	◯
Tiredness	◯	◯	◯	◯
Headache	◯	◯	◯	◯
Eyestrain	◯	◯	◯	◯
Difficulty focusing	◯	◯	◯	◯
Blurred vision	◯	◯	◯	◯
Nausea	◯	◯	◯	◯
Dizziness	◯	◯	◯	◯
Increased sweating	◯	◯	◯	◯

2. **Circle the picture below that indicates your feelings or emotional response to the TimeSnap virtual reality experience.**

1	2	3	4	5
You feel like you're inside the picture, a part of the story, or a part of the action		<<<<<<Somewhere in between these 2>>>>>>		You feel like you're outside the picture, removed from the story, or not part of the action
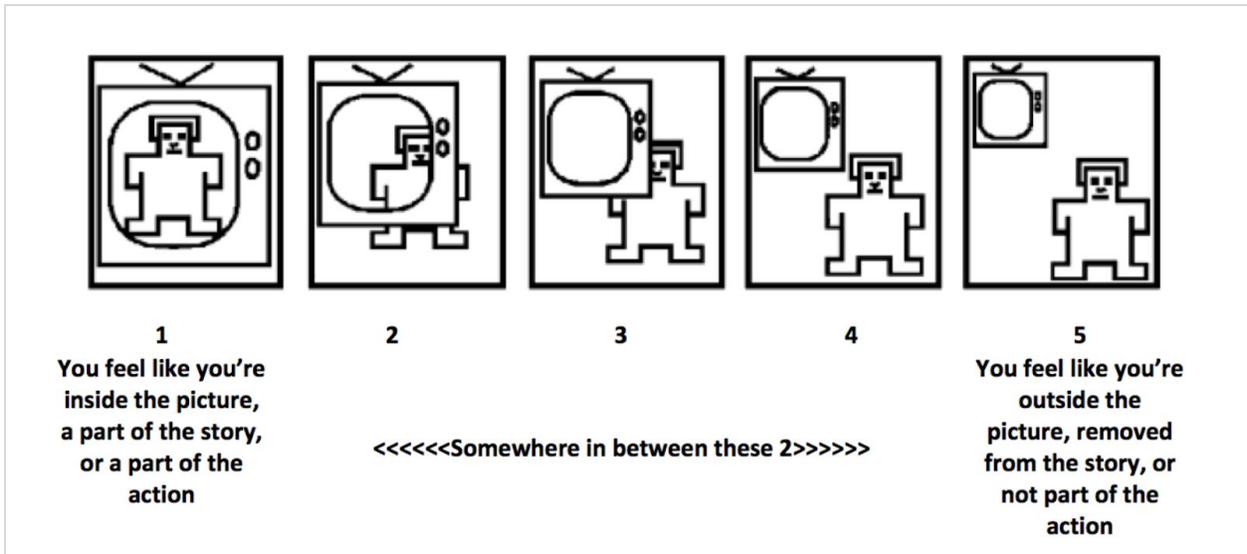
3. What do you remember from the VR interactive?

Jot some notes about what you experienced inside TimeSnap VR. For each type of information you encountered, write everything that comes to mind.

Mission Objective (what do you remember about the mission Dr. Wells gave you?)	
People (which people did you meet and what do you remember about them)	**Rooms** (which rooms did you visit, and what do you remember about them?)

Objects (which objects did you see or pick up, and what do you remember about them?)	**Conflicts** (what's an example of a conflict you heard about between the British soldiers and the colonists?)

Questions 4-7 ask you about your experience playing the VR interactive

4. **What did you like most about the VR experience?** (Choose one)

   ❏ The feeling of 'being there' back in time

   ❏ The way things looked (the graphics)

   ❏ The way things sounded (the audio)

   ❏ Picking up objects and examining them

   ❏ Listening in on people's thoughts

   Other: _____

5. **What if anything did you find *confusing* or *challenging* about the VR experience?** (Select all that apply)

   ❏ I wasn't always sure what my mission was — i.e., what I was supposed to be doing.

   ❏ I would get messages about things I had done, and I wasn't sure what they meant.

   ❏ I didn't always know what Director Wells was talking about.

   ❏ I wasn't sure what words like 'field notes', 'causes' and 'evidence' refer to.

   Other: _____

6. **Which of these sources of information did you find most *interesting*?** (Choose one)

❏ Director Wells

❏ Objects

❏ 'Mind melding' with people

❏ Documents / Engravings

  Other: _____

7. **Which sources of information did you find most *helpful* in accomplishing your mission?** (Choose one)

❏ Director Wells

❏ Objects

❏ 'Mind melding' with people

❏ Documents / Engravings

  Other: _____

8. **Briefly say what, if anything, you think you learned from playing TimeSnap VR**
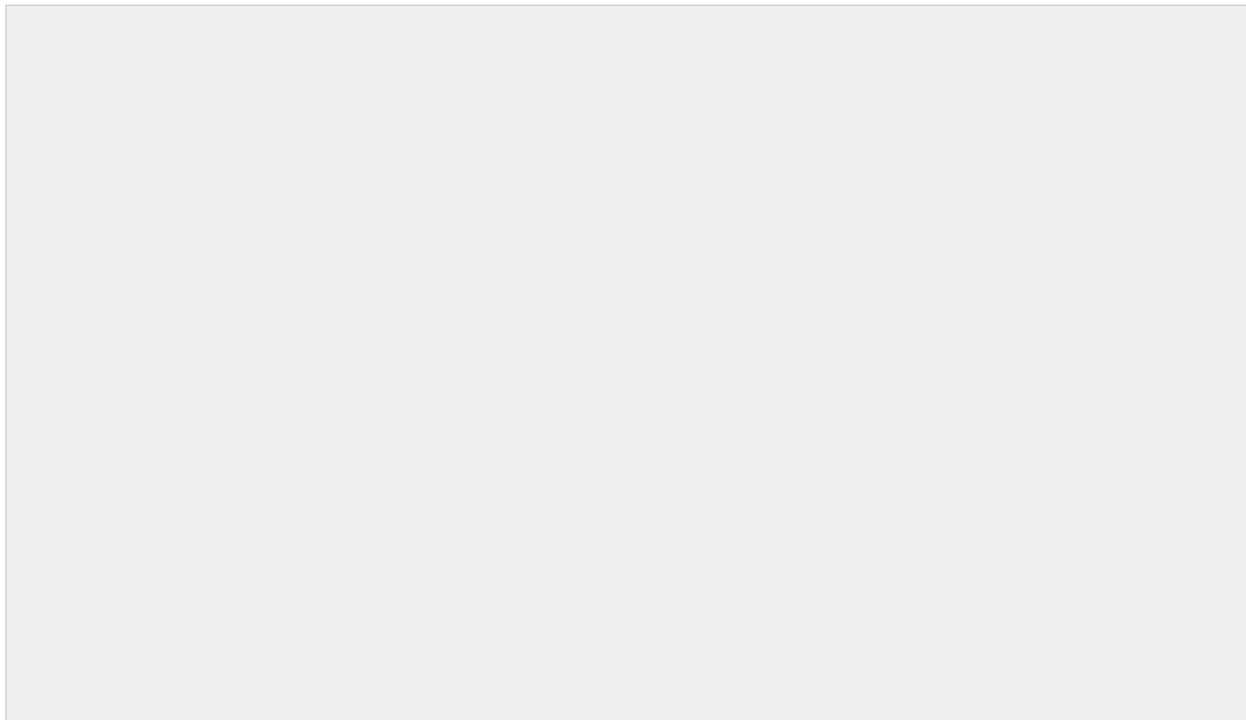
Appendix C: Teacher Interview Protocol

Relevant research questions:
- Feasibility: (Q2) Is the teacher able to integrate students' experiences in VR with the associated classroom activities to achieve the learning objectives?

- Fidelity of implementation: (Q3) What modifications does the teacher make to the lesson activities or curriculum materials, and why?

- Student impact: (Q4–6) As compared to peers in business-as-usual classes, do high school students who participate in TimeSnap VR-supported lessons demonstrate greater content knowledge of topics in American history, and more proficiency with historical thinking skills?

Thanks for taking the time to talk to us about your experience teaching with Mission US: TimeSnap. This interview should take about 45-60 minutes. And I just want to remind you that we're equally interested in hearing negative comments as positive comments, so we encourage you to be completely honest and not worry about hurting our feelings.

With your permission, we'll be audio recording this session because we don't want to miss any of your comments. This recording is for note-taking purposes only, and will not be shared with anybody outside of our research team. We won't use any names in our reports.

Before we begin, do you have any questions?

If you consent to us audio recording the interview, I'll start that recording now.

Lesson Implementation:

1. In what ways, if any, was this experience of teaching with virtual reality technology the same as/different from what you expected?

2. On a scale of 1-5, how confident are you that you could effectively use a VR experience like this one as a part of your regular classroom instruction?

   a. Please explain your answer.

3. What challenges did you have, if any, in using VR and the instructional materials?

   a. Is there anything you would do differently if you were to teach with TimeSnap again within the context of your regular instruction?

4. What types of curriculum resources would be most helpful in supporting you to incorporate this type of VR experience into your regular classroom instruction?

5. What types of professional development resources or activities would be most helpful in supporting your ability to meaningfully incorporate this type of VR experience into future instruction?

6. What data would be helpful for you to see in relation to what students are doing inside of the VR?

   a. How would you use this data?

Teacher Perception of Student Experience:

1. In general, how do you think most of the students experienced the virtual reality technology?

   a. *Probe if necessary:* Did their actions and comments fit with your expectations? How was their behavior similar to/different from what you typically observe with this content and/or grade level?

   b. What struck you as students' most significant takeaways and/or learning outcomes? What makes you say that?

   c. Did you observe any misconceptions or gaps in understanding that you felt could have been better addressed?

   d. Do you think TimeSnap had any effect on their understanding of the causes of the Boston Massacre? What makes you say that?

   e. Do you think playing TimeSnap had any effect on how they think about evidence of the past?

2. What information do you think would be most helpful for students to be able to see after they come out of VR to support discussion and document analysis?

3. We talked with students about whether they trusted what they heard in the game, and whether it was

Wrapping up:

1. Is there anything else you'd like to share?

Appendix D: Student Focus Group Protocol

1. What sticks out most about your experience in TimeSnap?

    a. Did anything surprise you?

2. What parts or features of TimeSnap do you feel best helped you learn as a history student? How?

3. Were there any parts of the experience that you felt did not help you learn because they were:

    a. Hard to understand?

    b. Distracting?

    c. Just not particularly helpful or interesting?

4. What did you understand about your mission/goal in TimeSnap?

    a. Were Director Wells' instructions clear?

    b. Were there any points when you did not understand what you were supposed to do?

5. If you had the ability to change the design of this experience, what would you change, add, or take away?

Paul Revere Image

6. Can someone come up and describe what's going on in this scene?

7. What do you think this scene has to do with the Boston Massacre?

8. Did this scene give you any different perspective on Paul Revere or causes of the Boston Massacre?

9. Had you seen this landing print before? Did seeing it in the interactive make you think about it any differently?

Preston Image

10. Can someone describe what Preston was writing in his letter?

11. Did that letter affect how you thought about the causes of the Boston Massacre?

12. To what extent do you trust what he's saying? (Do you have reason not to trust it?)

Choosing evidence

13. Can someone describe what they were supposed to do here?

14. What does this have to do with your mission?

15. Which item did you choose? Why? Did anybody choose another item? Why might someone choose the item on the left? What about the item on the right?

16. How much do you trust that the historical events, people and perspectives you saw in the VR were accurate?

17. Would you say that TimeSnap was more like a documentary or a historical fiction movie?

Appendix E: Classroom Observation Protocol

Instructions for using this form
1. Complete the form
2. Download as a word doc
3. Rename the file TS2_ON_RN_*Teacher#Lesson_YourInitials_Date*
   a. ON= observation notes RN = Reflection Notes
   b. Lesson: BM or FSA
   c. Date: YYMMDD
4. Save in Box TS > Data > ON >

RQs the observation might address

Research Question	Sub-construct
RQ2: Is the teacher able to integrate students' experiences in VR with the associated classroom activities successfully to achieve the learning objectives? (*Feasibility*)	
RQ3: What modifications does the teacher make to the lesson activities or curriculum materials, and why? (*Fidelity of Implementation*)	- Was there anything that stopped the teachers from using the materials as written? - Were teachers able to use the materials within a reasonable window of time? - If the teacher made modifications, what reasons did they give?
RQ6: How do students relate to and experience history content in a VR-supplemented lesson? (*Student Impact*)	- What types of information did students react to most? - What types of information did students retain most? - To what extent, and in what ways, are students able to use the information from VR in the non-VR lessons?

Guided Reflection Questions

1. In what ways, if at all, did the teacher reference students' experiences with the VR in the lesson? (RQ2)

2. How did the teacher address the learning objectives? (RQ2)

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3. Is there evidence that students achieved the learning objectives? (RQ2)

4. What modifications does the teacher make if any to the lesson? (RQ3)

5. Write up notes about anything students say related to their experience of the history content, or any connections they talk about between what they're doing in the lesson and what they did in the VR experience. (RQ6)

Running notes: