Oliver Baltay (ob2281)
Jet Harper (jmh2287)
Neil Kumar (nk2739)
Yogi Mutneja (ym2578)
3D User Interfaces
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Final Project Documentation

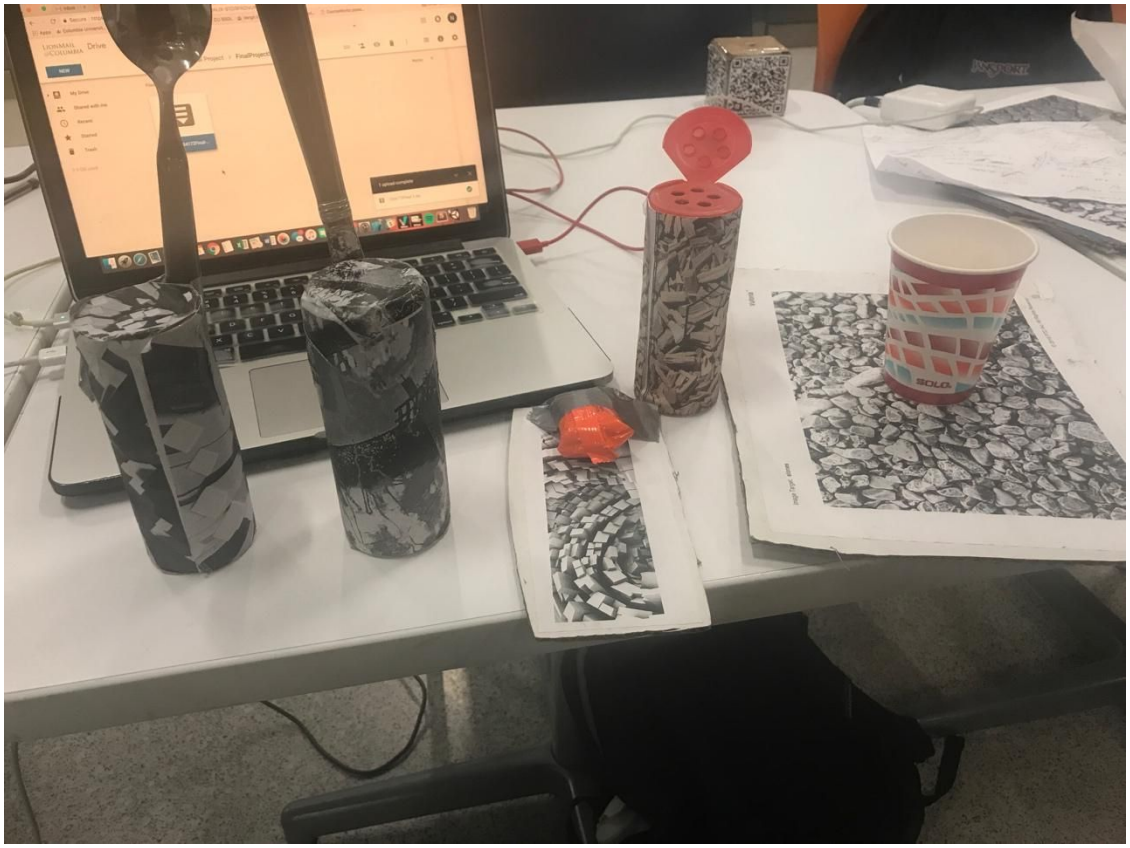
The purpose of the app is to annotate the yarn dyeing process in the making and knowing lab.

For this, we have two modes for two different use cases. The first is the walkthrough mode in which we guide the user step by step through the yarn dyeing process in the lab. The second is the free-play mode in which we tell the user about the yarn dyeing process and the different dye-mordant color combinations before they go to the lab.

The guiding principles behind all our design choices for the app is that we try to make it as isomorphic as possible for the user and include a lot of natural interactions. The app is being used by the user in the lab and in general to know more about the process. We feel that he would be able to learn much better if the interactions are kept as close to the real world as possible.

Walk-Through Mode

Goal: The goal of the walkthrough mode is to lead an inexperienced member of the Making and Knowing Lab through the steps necessary to dye yarn from beginning to end. Guided by our initial design principles of making this app as isomorphic and natural as possible, we settle for a tangible user interface as a design choice for this section. By utilizing a tangible user interface, users understand what physical objects are necessary in real-life and how to interact with them. The interactions take place between real physical objects and are tracked by the app giving user feedback and guiding him through the next steps. This way, other than receiving visual feedback from the app, he also experiences tactile feedback from using the real world objects.



Each Cylinder Target / Image Target is attached to a physical object that the user would actually use in the lab during the yarn dyeing process.

In the image above, we try to use physical objects with image targets around them as a proof of concept. The spoon represents a spatula, knife a hammer, salt shaker a mordant and chocolate wrapper a dye. The cup represents a beaker. We assume that the beaker is always placed at the center of the image target and thus all interactions that happen with it are based on that.

We now go through the steps one by one.

<u>Instructions</u>
The 4 Steps of Yarn Dyeing

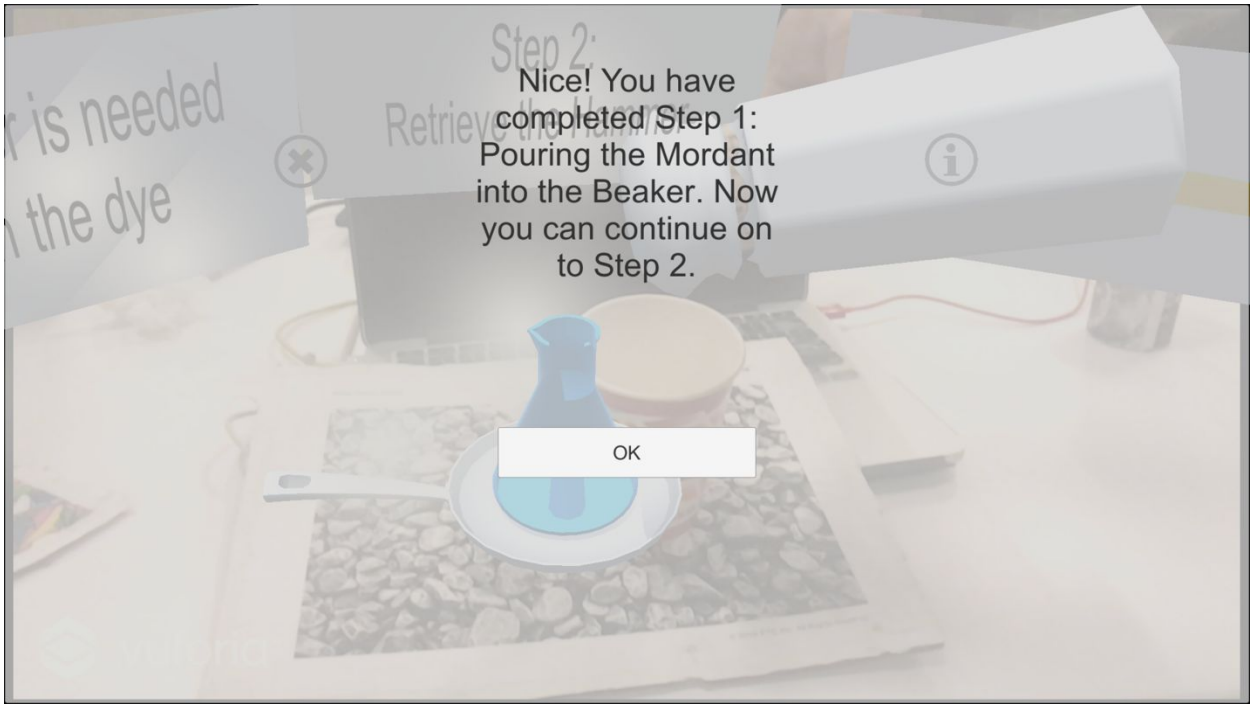
Step 1:
A: Retrieve the Mordant. Mordant emulsifies the dye, so it must first be added to the beaker.
We use wayfinding to look for the mordant and travel to fetch it. We get a real time feedback for the travel component and the numbers update on the wand image target as we go closer and closer to the mordant. We follow a compass metaphor as a design choice for wayfinding as it seems the most intuitive and natural, thus in line with our design

principles. Once the mordant is brought back to the workspace, it automatically detects it and updates to the next step.

Initially, the Quads indicate what the user must do (center quad), what the step accomplishes (left quad), and what the object looks like (right quad).

B: Pour the Mordant. Pouring the Mordant into the beaker creates a base layer.

To detect the pour gesture of the physical object, we track the top most part of the object and as soon as that hits the beaker, we conclude that the person must be pouring. We fixed this behavior after making the video. Earlier it was buggy since we were tracking rotations instead of the top part of the target.

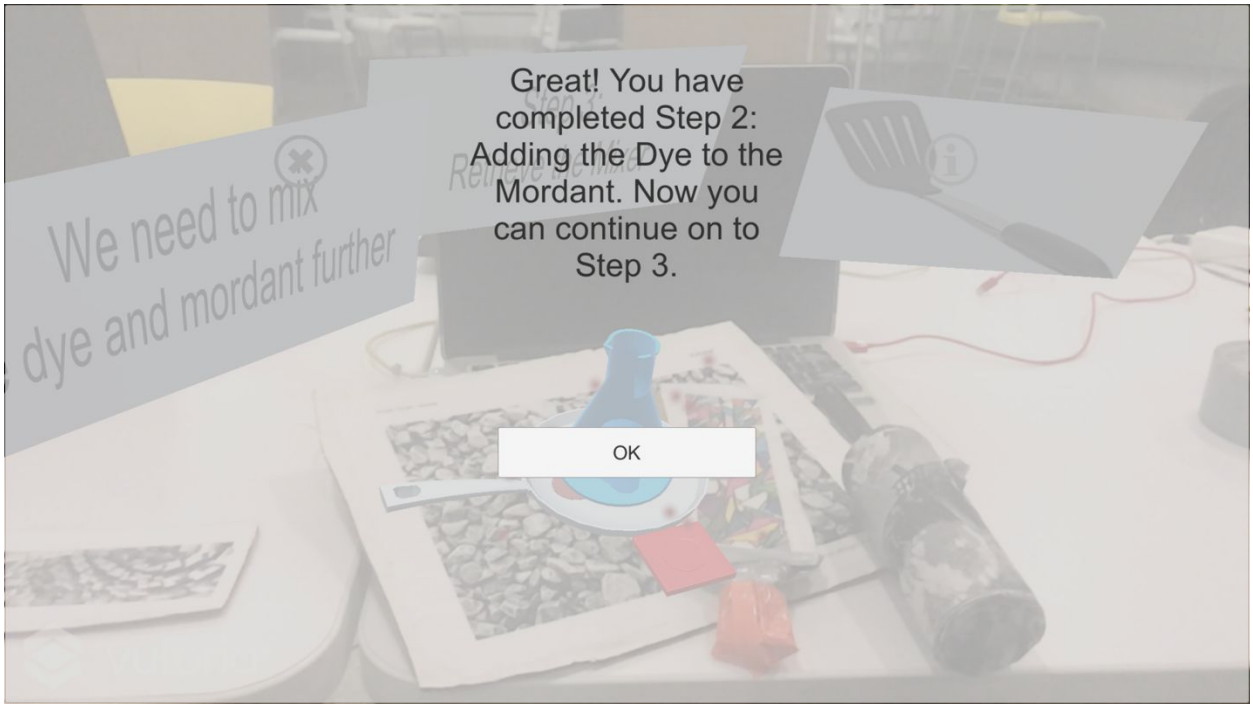


Completing the instructed task initiates the next step and indicates so by showing a popup. Additionally, we utilized animations to better match the real world and show that the interaction was achieved.

Step 2:
A: Retrieve the Hammer. In order to properly mix the dye, it must be crushed with a hammer. Next, we wayfind and travel to fetch the hammer and the scene updates when you fetch it.

Now in step 2, the user is asked to “crush” dye into fine particles. The “Acid” Image Target is overlaid with the dye physically and virtually to show that the physical object (Hammer) is actually interacting with the dye.

B: Crush the dye with the hammer, and mix it smoothly into the beaker.



Hitting the Hammer against the dye shows a nice animation indicating that the dye is now in the beaker. We are using collisions of the virtual objects to detect the hammering gestures of physical objects.

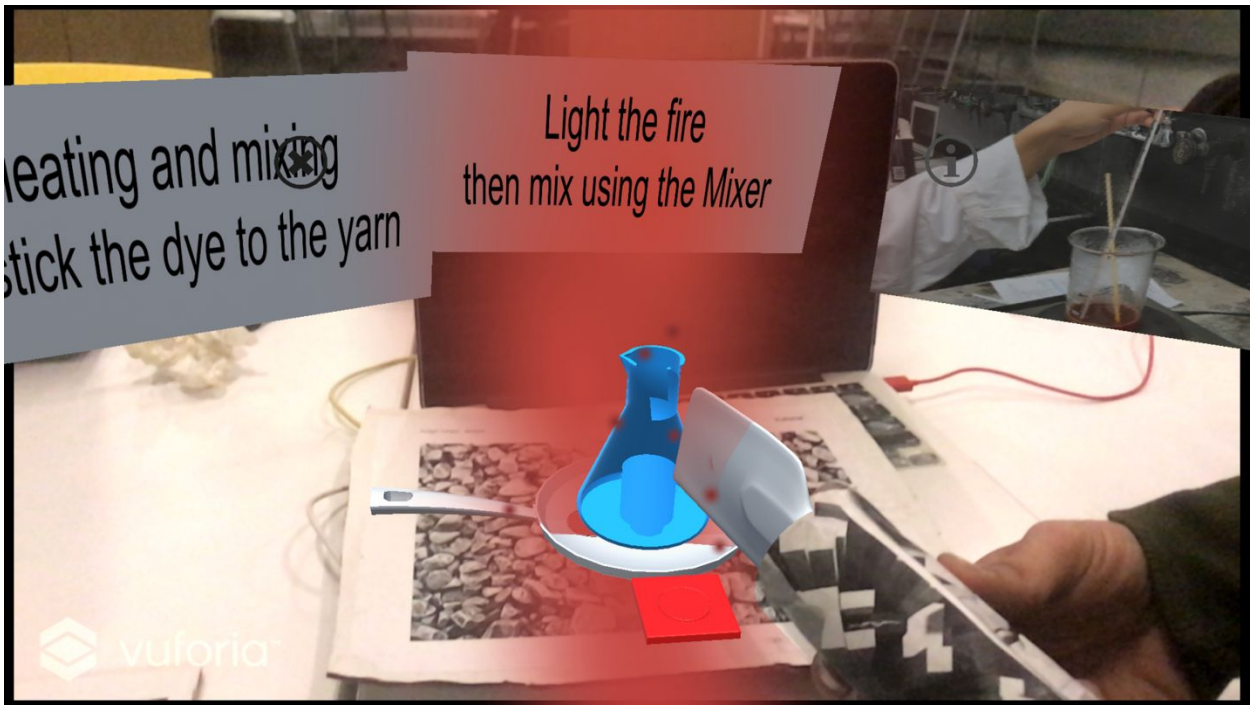
Step 3:

A: Retrieve the Mixer (Spatula). It is important to thoroughly mix both the mordant and dye together.

We wayfind and travel to fetch the spatula. We assumed in the beginning that the actual physical beaker is placed in the center of the image target and can not be moved. We represented this by using a physical cup placed there. Thus when the virtual spatula interacts with the virtual beaker placed in the same position as the real beaker, we detect the physical stirring action.

B: Light the fire underneath the beaker and mix the mordant and dye over heat.

We then press the heat button and we see a fire animation in the screen which gives the user a visual feedback as well.

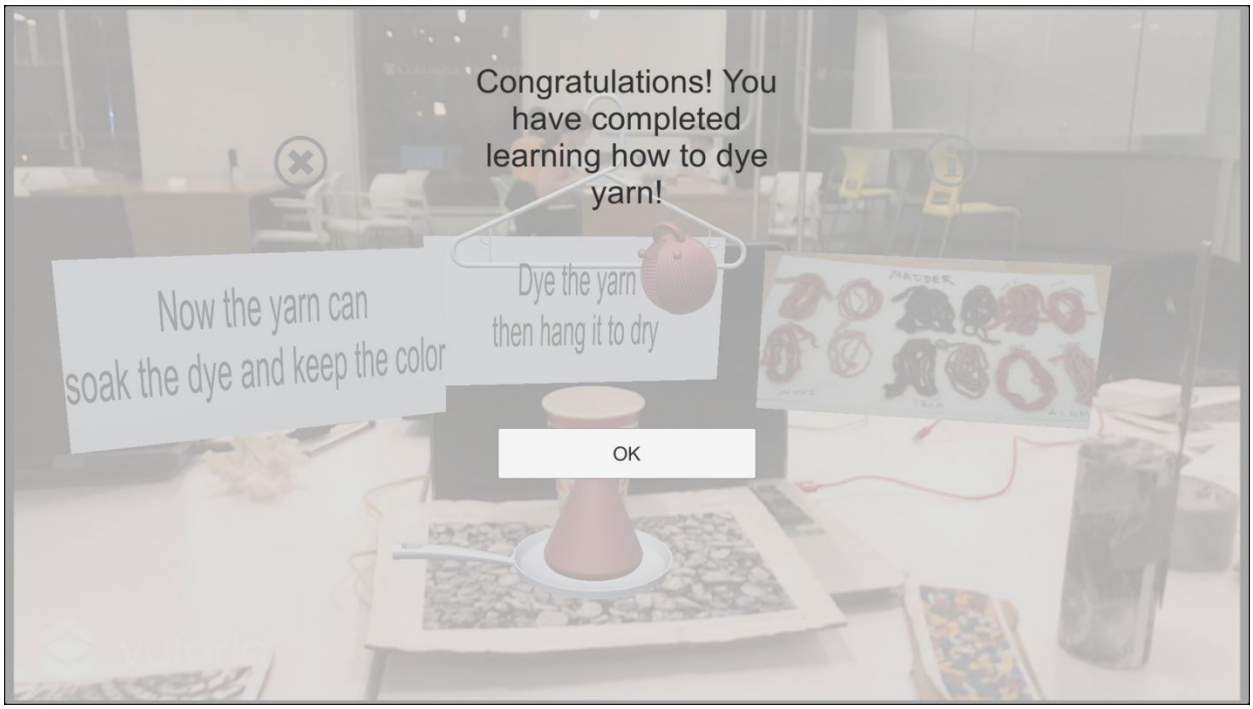


Once the mixer is retrieved, the user should “heat” the beaker by pressing the mixer against it then “stir” by moving the mixer inside the beaker for a certain amount of time.

Step 4:

A: Mix the yarn in the beaker and allow it to take in the dye color.

B: Hang the yarn to dry after stirring.
Lastly, as a fun little step we give the user a virtual dye to interact and play around with. The user can dye it by dipping it into the dye that he just created. He can then hang the yarn to dry on the virtual hanger placed in the app and that's when this mode ends.

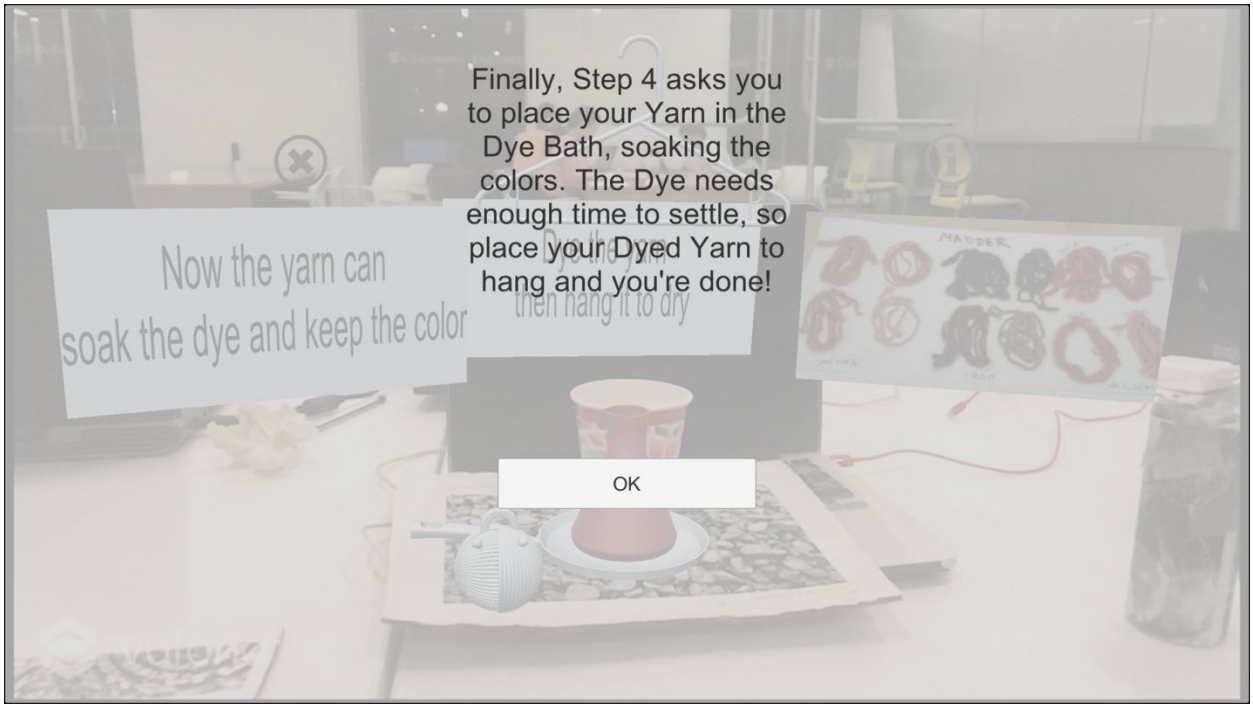


Finally, in step 4 once the user "dyes" the yarn by placing it in the beaker using the pointer, once he hangs the yarn the process is complete and he can re-start either mode.

Yarn dyeing Instructions: We understand that giving the user proper instructions in the lab is probably the most important and useful feature of the app. Thus, we make sure that this task is done especially well by the app. We used modified 2D menus (Quads) for this purpose following a whiteboard metaphor. The rationale behind using this metaphor is again guided by our initial design principle. A whiteboard seems to be the most natural thing to convey instructions through in a lab and thus we decided to implement that. To make sure that the text is clear and legible, we allow the user to select and scale for visibility and legibility using an integrated selection technique. We choose to locate the instructions in the 3D space to increase user control and increase the amount of information that we can display in a constrained screen space. The quads take up less screen space than 2D elements, and they mimic the action of a whiteboard.[1]

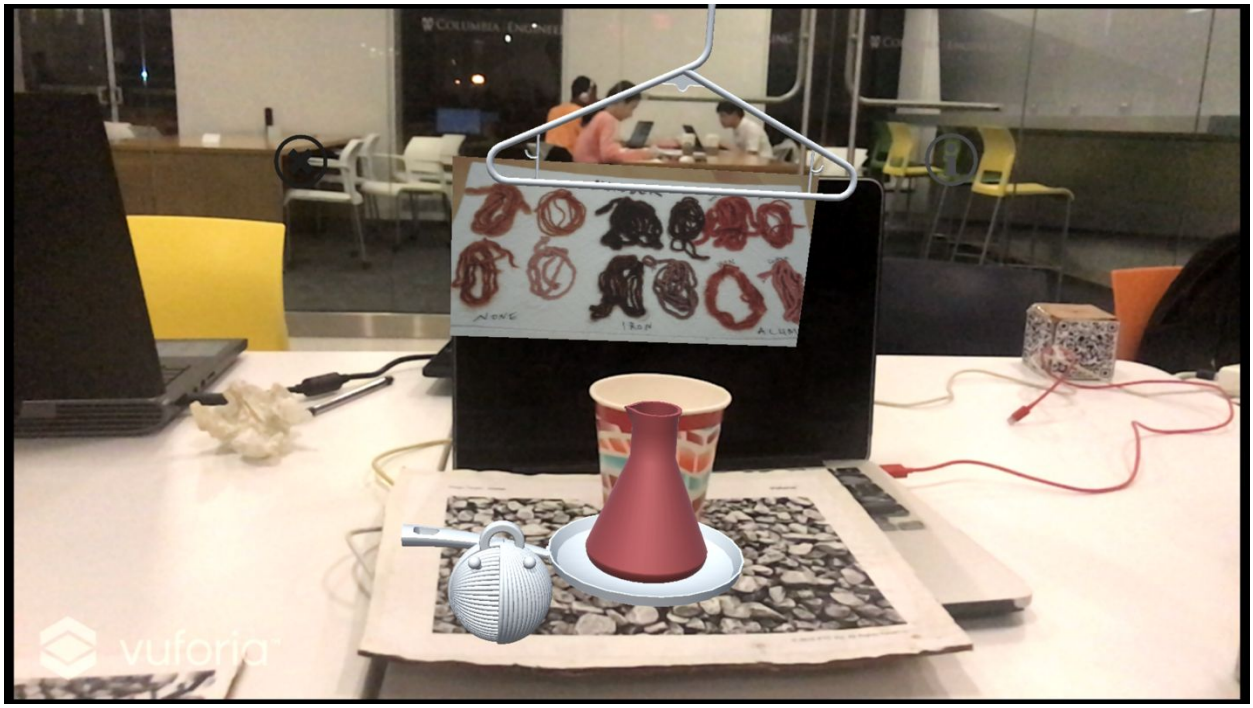
[1] "Adapted 2D Menus Menus that are simple adaptations of their 2D counterparts have, for obvious reasons, been the most popular group of 3D system control techniques. Adapted 2D menus basically function in the same way as they do on the desktop."
"Menus are well suited for providing good structure for larger numbers of functions, and most users are familiar with the underlying principles (interaction style) of controlling a menu. On the other hand, these menus can occlude the environment, and users may have trouble finding the menu or selecting items using a 3D selection technique."

Following our design ideology. Apart from scaling, we can also select the whiteboard and it pops up in the center for us to see even more clearly. The font size was set to large so that it is clearly visible. The background was chosen to be white and the font color as black for the same reason. To compensate for the camera viewing angle, we follow a sunflower metaphor as the whiteboards dynamically rotate and follow the camera so that the text is clearly visible from all viewing angles.



Clicking the (i) logo in the top right presents more-detailed information tailed for each step. This is not initially shown to maintain the aesthetic design.

LaViola, Joseph J., Jr.; Kruijff, Ernst; McMahan, Ryan P.; Bowman, Doug; Poupyrev, Ivan P.. 3D User Interfaces: Theory and Practice (Usability) (Kindle Locations 7874-7877). Pearson Education. Kindle Edition.



Clicking a single Quad hides the others and places it in the center, helping visibility.

By holding a press on a certain Quad and interacting the pointer with it, the user can scale each Quad. This aids readability.

Selection/Manipulation

In Walkthrough mode, we use physical objects with image/ cylinder targets in order to make the process as isomorphic as possible. Our tangible user interface takes the form of simple cylinder targets that correspond to items present in the Making and Knowing lab that are necessary for the process. The walkthrough mode is intended to orient new students to the process and the space, so the inclusion of the tangible user interface increases user presence and engagement in the lab. This also allows for more isomorphic manipulation of the containers and tools so that they more closely mirror the actual processes.[2] We also use gesture based interactions such as pouring and hammering to accomplish interactions. As objects are mostly physical the selection and manipulation are real time in the walkthrough mode. We can however select the information boards to make them appear in the center. They can also be scaled up and down. They also rotate based on the camera viewing angle. We provide a virtual yarn at the end of the process to provide fun interactions to the user. He can translate and rotate the yarn to wherever he wants. The process ends when he hangs the yarn to the hanger after pouring it in the dye. Additionally, when the user is wayfinding, once he detects the physical Cylinder Target the arrow on the wand becomes the pointer, indicating that the object has been selected.

We now discuss some of the relevant heuristics that our app satisfies.

Help and documentation

In addition to the features present in freeplay mode, during the walkthrough mode, the user can select the information button on their phone screen and access information about the step they are currently executing. This information is more in depth than the basic ins and outs of creating dye and soaking yarn, so it doesn't need to be in immediate view for the user to see in the same way that the instructions do. Therefore, we decided to make this information accessible but unobtrusive so that the user can select to view it if they want to. We did that by using the whiteboard metaphor we explained above.

User control and freedom

We included an exit button (similar to Free-Play mode) to exit Walkthrough mode at any time.

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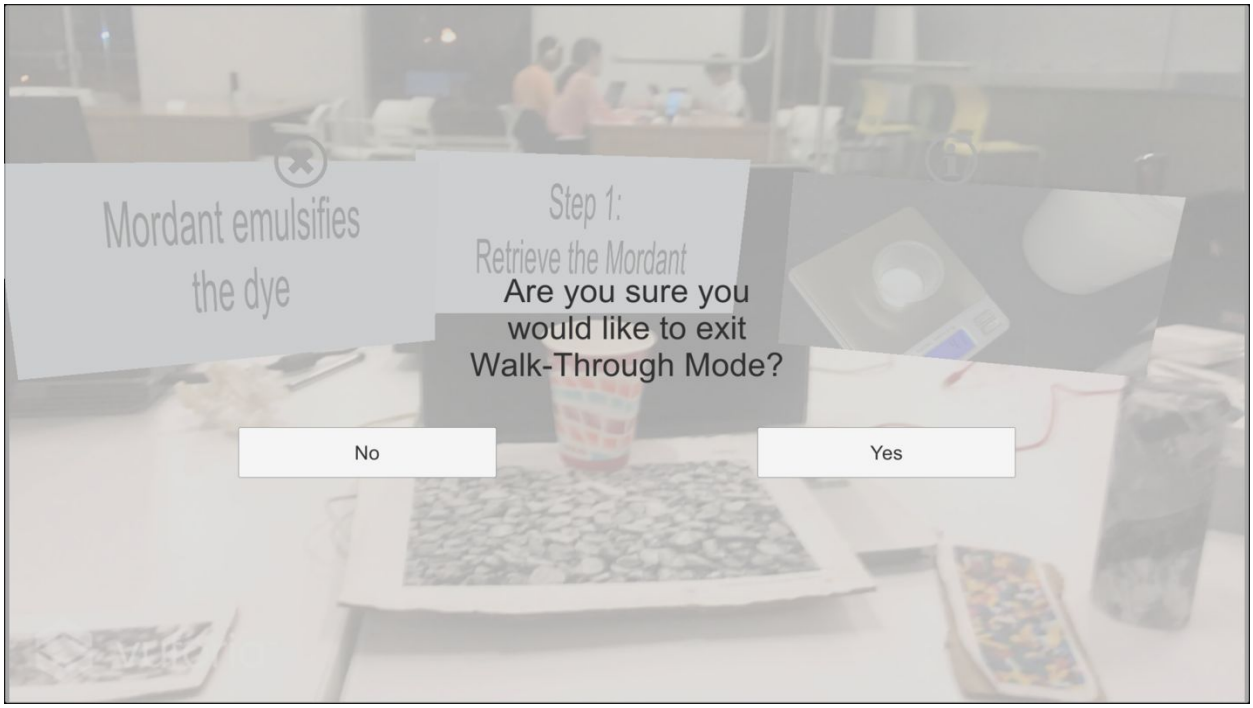


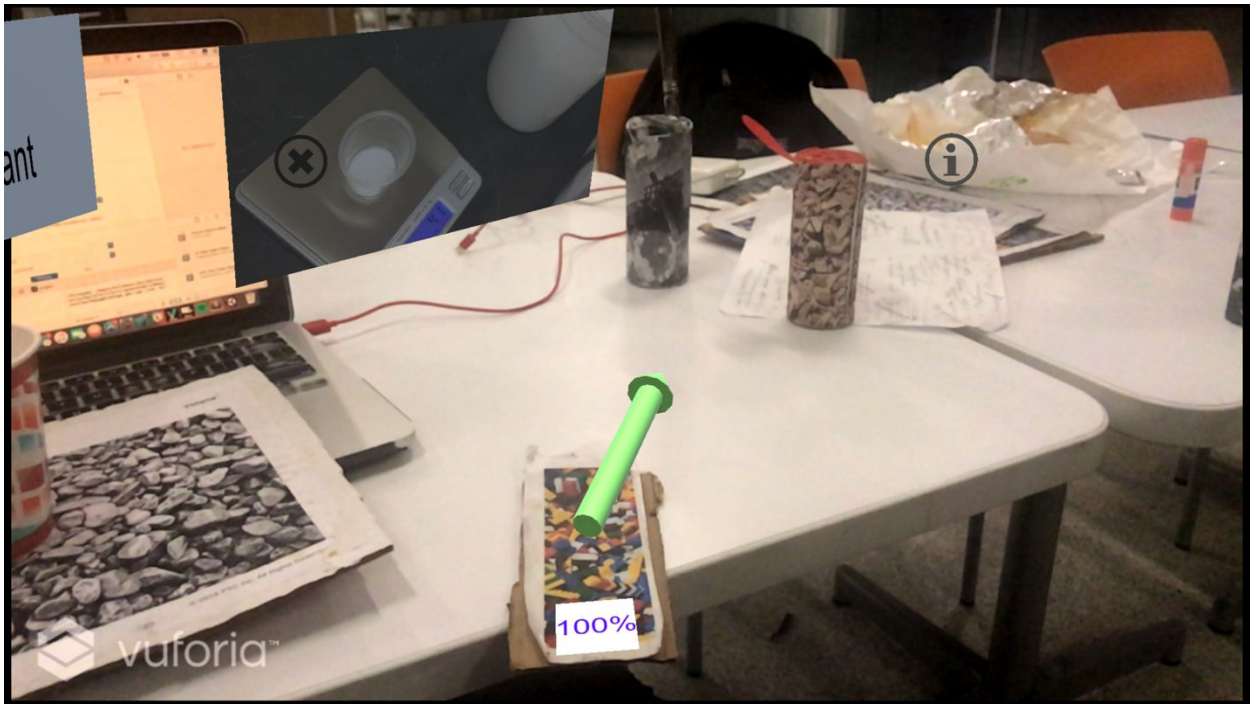
By clicking the (X) in the top left, the user can exit Walk-Through mode.

Feedback/visibility of system status

In addition to measures present in freeplay mode, the walkthrough mode includes more animations such as crushing the dye or pouring the mordant. These animations even more closely mirror real world results because they are triggered by physical interactions with the TUI.
At the end of each step we included a 2D popup that alerts the user to the completion of the task and allows them to move on to the next one. This is a part of how we chose to keep the user clued in to what their progress is through the lesson. The step number is always written on the whiteboard in the app so that the user knows what step he is at.

Wayfinding and travel

Wayfinding: we chose to implement wayfinding in our walkthrough mode in order to direct the user to the correct dye or mordant needed for the step. For this task we used a modified user-centered virtual compass metaphor. When the ingredient retrieval task is initiated, an arrow appears on the controller image target which points in the direction of the cylinder target that corresponds to the needed ingredient. We chose this technique because it was the most straightforward way to manifest a virtual compass metaphor while utilizing 3 different directions. During wayfinding, we also indicate to the user their proximity to the target using a relative distance that appears on the wand, helping the user travel more effectively.



When the user starts a new step, they are led to the new Cylinder Target (Tangible Object) to use for that step. The percentage at the bottom of the wand indicates the relative distance to the object, and we did so because actual units did not provide as much information.

Before the user begins the walkthrough, they must scan the space for the cylinder targets that they will be using so that they can be tracked for wayfinding purposes. This is necessary because of the limitations of Vuforia's tracking system, helping to accelerate the process.

To accelerate the wayfinding process, we ask the user to scan each Cylinder Target before starting the walkthrough mode. This makes the 3D direction handling and distance calculations better.

Error prevention

During each step of the walkthrough, user interaction is constrained to the interactions needed for the current task. If a user tries to execute an action during the wrong step, the interface displays a pop up alerting the user to the error. Additionally, we set the modified 2D display panels to always face the users camera in order to ensure constant visibility to prevent any errors.

Because the mixer is needed for step 3, trying to add it to the Lab now (step 1) indicates an error and prevents it from happening.

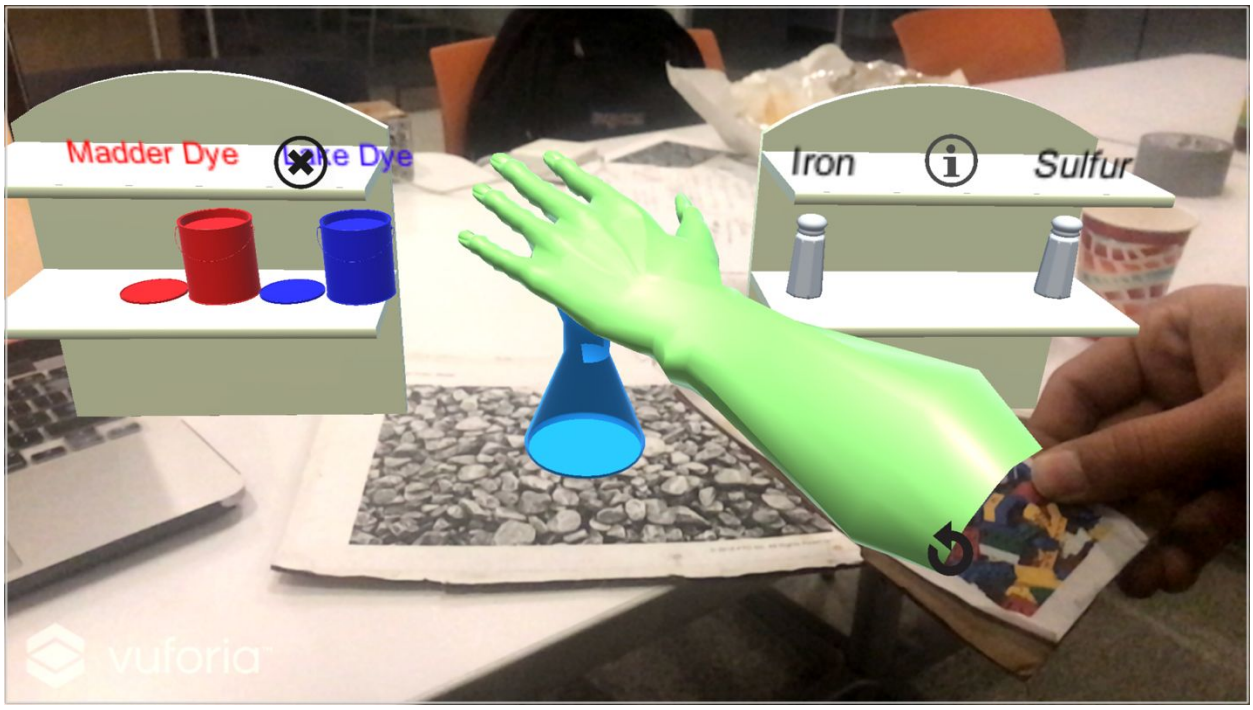
Free-Play Mode

Goal: To learn more about the dye combinations and lab procedure before going to and physically present in the lab.

Instructions

In freeplay mode, the user is free to execute various tasks in the process in a self-directed manner. All interaction is accomplished virtually using an image target as a simple virtual hand. This design choice is again based on our design principle of making our app as isomorphic as possible with natural interactions. The virtual hand metaphor extends naturally to humans. All objects in this mode are virtual since the user is not actually present in the lab. The user can select and "grab" a dye or mordant by touching the controller to an object on the shelf above the lab space, and by touching the object now attached to the controller to the beaker where the ingredient is supposed to go, the user can "drop" the ingredient to the mixture. The shelf is annotated so that the user knows which dye or mardant he is picking. The user is shown on the screen at all times what he has currently added to the beaker. He can also see this as the shelf is annotated and the object is not there under it if it has been added. When a mordant and a dye have been added, the beaker will turn to the color of the dye inside thus showing the user what color combinations are made from the different ingredients.

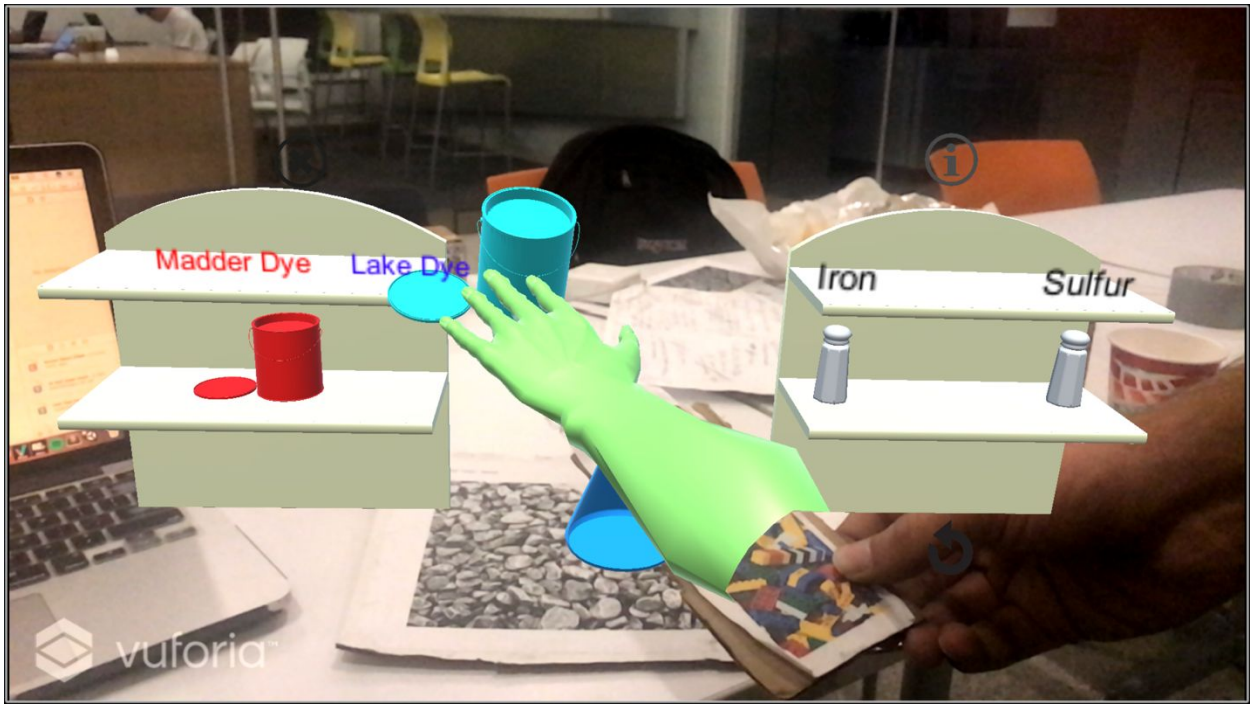
There is also an info button which has the details about the entire process that the user needs to follow in the lab in order to dye the yarn. He can thus go through them and read and learn more about the process. At all times the user can undo whatever action he took by pressing the undo button or can exit the mode by pressing the cross button.



The above photo shows the utilization of the Virtual Hand Metaphor.

Selection/Manipulation

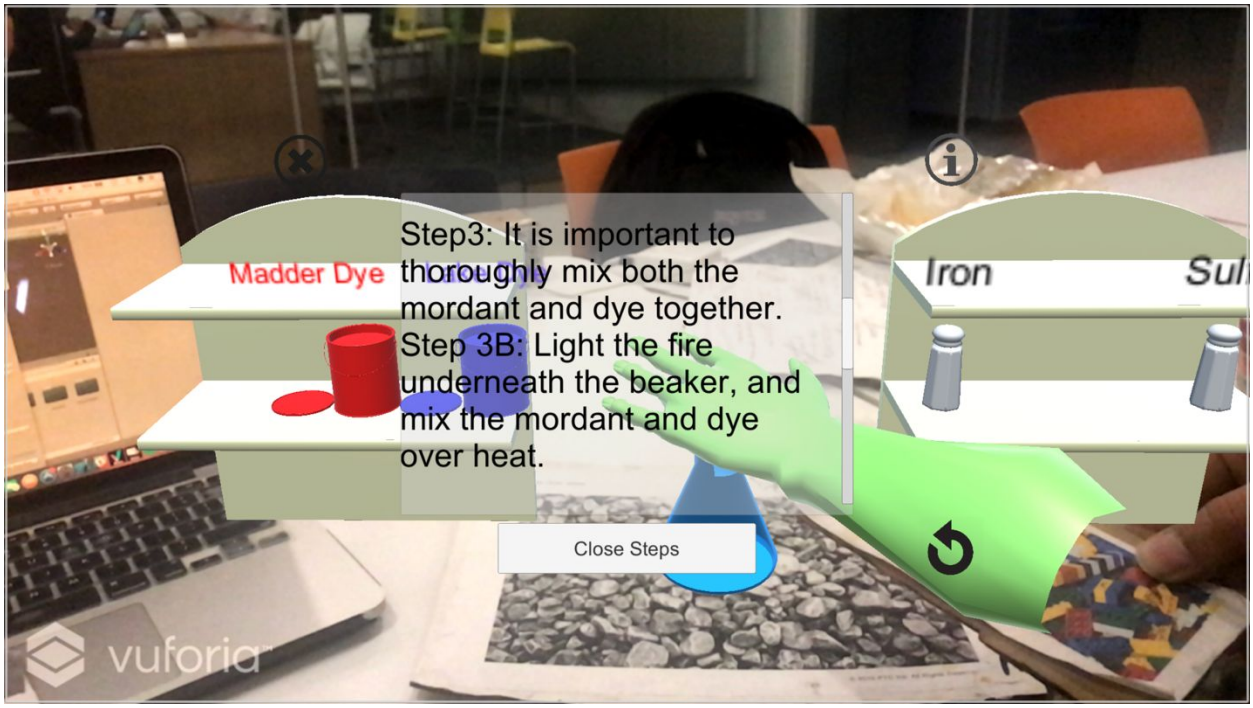
For selection and manipulation, we used a virtual hand metaphor, allowing the user to select isomorphically. Selection occurs when the virtual hand simply intersects an object. We chose this technique because it keeps interaction as isomorphic and intuitive as possible. When the items are selected they get highlighted as well to give the user a feedback that it is selected.



When items are selected, they are highlighted with a slightly lighter color to indicate selection.

Help and documentation

In order to tell the user more about the yarn dyeing process, we included a 2D information button that displays all the steps in the yarn dying process. We make this a scrollable text so that we can fit in a lot of information conveniently on the screen.

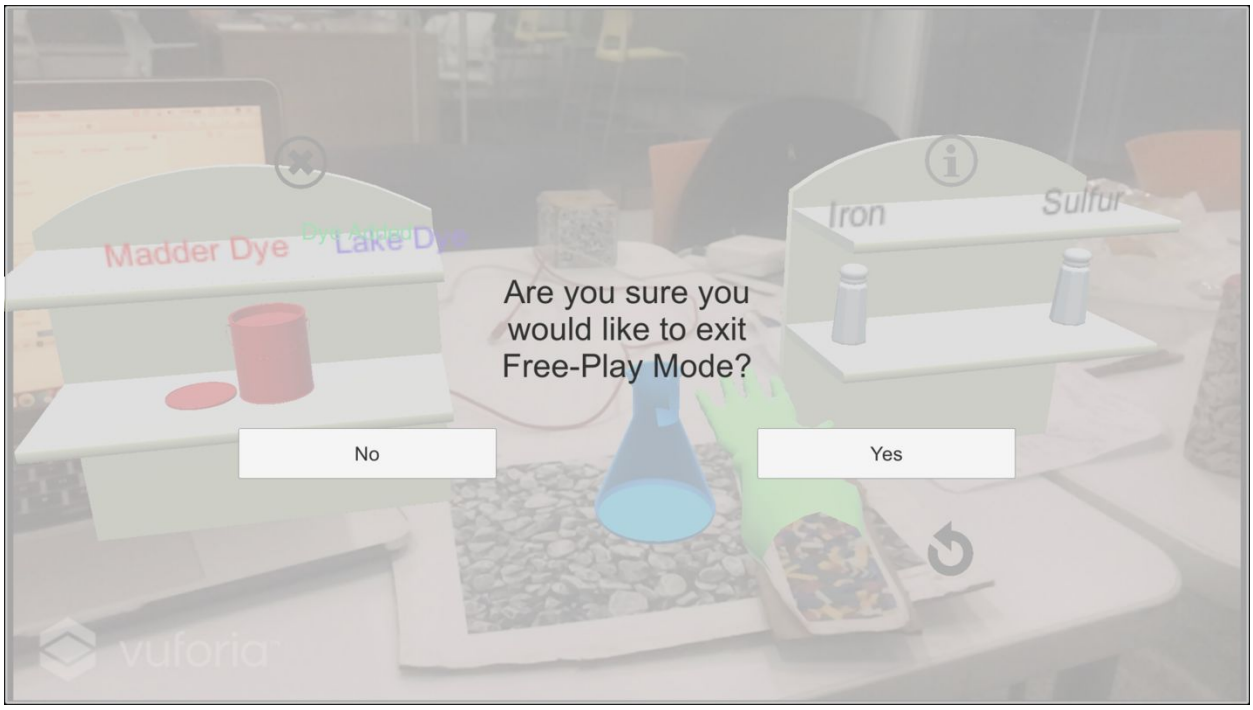


By clicking the (i) logo in the top right, the user can see all steps of the dyeing process during free play mode instead of doing the full process.

User control

We provided an exit button so that the user can end freeplay mode and return to the start screen in the event that they want to switch modes. The exit button, which is the image of a cross button which the user is familiar with, is present at all times on the screen.

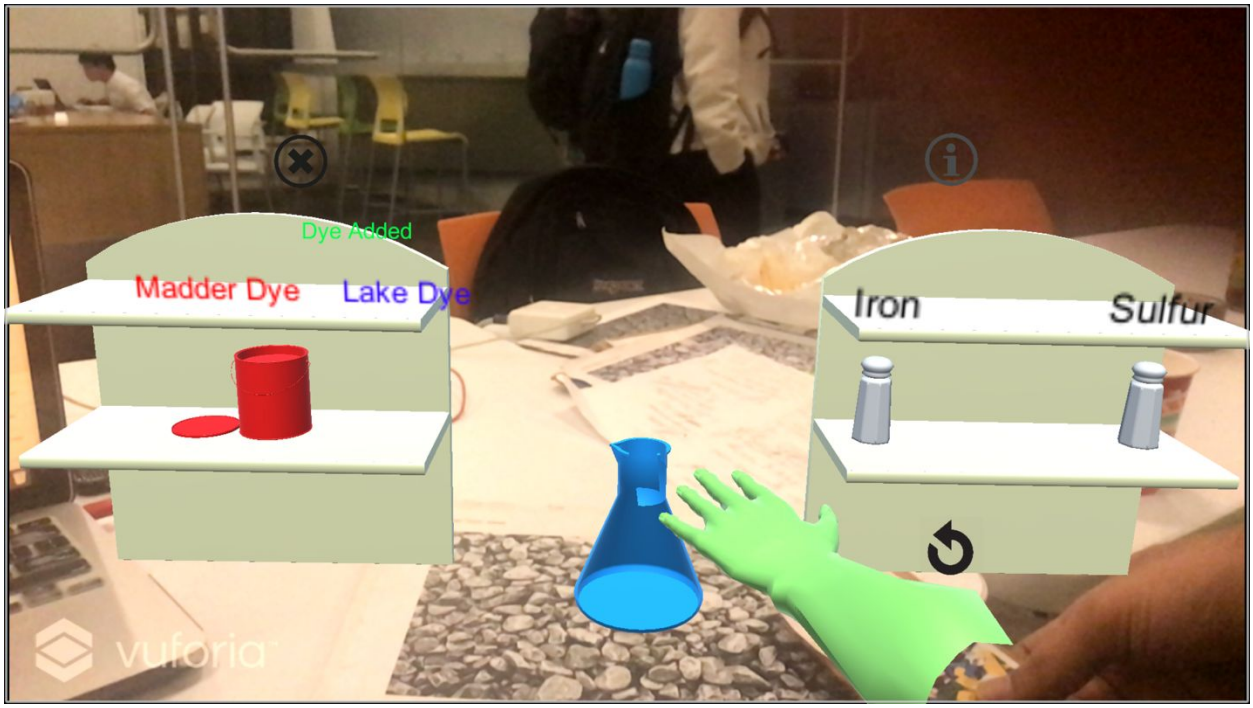
We also included an undo button so that the user can recover from mistakes or pick a different item.



By clicking the (X) button in the top left corner, the user can exit freeplay mode at any time. Also, as demonstrated in the video by clicking the “Undo” in the bottom right corner the user’s action is undone.

Feedback/Visibility of system status

When an object is selected its color is noticeably lightened to indicate selection, in addition to being transferred to the virtual hand. The beaker also updates to the color of the selected dye/mordant combination to indicate the resulting dye that would be created.



When a dye or mordant is added to the beaker, text in the top left corner indicates so, and undoing adding hides the text as it goes through the previous step.

We also annotate the virtual shelf so that the user knows which dye or mordant he is picking.

References

[1] (“Employ physical objects, surfaces, and spaces as tangible embodiments of digital information.” — H. Ishii)
[2] M. Slater, M. Usoh, and A. Steed. Taking steps: the influence of a walking technique on presence in virtual reality. ACM Transactions on Computer-Human Interaction (TOCHI), 2(3):201–219, 1995.
[3] All quotes used above taken from LaViola, Joseph J., Jr.; Kruijff, Ernst; McMahan, Ryan P.; Bowman, Doug; Poupyrev, Ivan P.. 3D User Interfaces: Theory and Practice (Usability) (Kindle Locations 7874-7877). Pearson Education. Kindle Edition.
[4] Ullmer, Brygg, and Hiroshi Ishii. "The metaDESK: models and prototypes for tangible user interfaces." *Proceedings of the 10th annual ACM symposium on User interface software and technology*. ACM, 1997.
[5] Azuma, Ronald T. "A survey of augmented reality." *Presence: Teleoperators & Virtual Environments* 6.4 (1997): 355-385.

[6] Jones, J. Adam, et al. "The effects of virtual reality, augmented reality, and motion parallax on egocentric depth perception." *Proceedings of the 5th symposium on Applied perception in graphics and visualization*. ACM, 2008.
[7] Goldiez, Brian F., Ali M. Ahmad, and Peter A. Hancock. "Effects of augmented reality display settings on human wayfinding performance." *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)* 37.5 (2007): 839-845.