Democratizing interactive, immersive experiences for science education with WebXR

To the Editor — Objects and concepts of abstract nature, extreme sizes, poor availability or high purchase costs are often hard to understand and experiment with. We humans use models of various kinds to represent such hard-to-grasp entities in intelligible ways, not only for education purposes, but also in our own work. Traditional computer graphics, which allow the virtual creation and manipulation of three-dimensional (3D) objects, provide a particularly convenient way to generate, store and display such models. Nevertheless, the two-dimensional nature of input devices does not allow for an intuitive manipulation of those objects that are intrinsically 3D. In contrast, extended reality (XR) technologies enable immersive 3D views of computer models and intuitive ways to interact with them by overlying virtual representations of the studied objects onto the space surrounding the user and offering ways to handle the virtual objects with both hands (either directly or mediated by handheld devices) and/or by moving freely around them. The space can be either entirely virtual, as in virtual reality (VR), or an extended view of the real world, as in augmented reality (AR).

Unfortunately, access to these technologies is far from mainstream, and thus, they are permeating applications only slowly, delaying the 'revolution' that they were supposed to pose for work, entertainment, and most importantly, education[1]. The main problems that limit the adoption of XR tools are: the high costs and cumbersome nature of the hardware needed to generate high-end immersive experiences; the many different devices competing in the market, each with its own technology and software drivers; and the continuously evolving hardware and limited cross-device compatibility. The advent of XR for consumer devices such as smartphones, tablets and laptops alleviated these limitations, conferring these technologies a much wider reach. Still, they require software installations and regular updates, which may be unauthorized in educational settings, and have limited cross-device compatibility. In addition, development of regular XR applications is limited to expert programmers.

We pose that the real revolution in multimedia content for education is coming by the hands of WebXR, the new standard for XR running through regular web pages[2].

In brief, WebXR is a specification defined by the World Wide Web Consortium to provide standardized client-side code access to the device's sources about the position and orientation of the user in its physical location, and about the available output displays, unifying the creation of XR experiences across devices. From the developer side, WebXR is guaranteed to be compatible across devices, such as smartphones, tablets, computers, and even web-enabled VR and AR headsets. As a consequence, essentially the same code can be used across devices, as the browser takes charge of adapting execution to the specific forms of input and output available in each device. Particularly for academics and educators who might not have expertise in programming, web programming provides a relatively easy way to implement ideas[3]. In addition, WebXR programming benefits from the seamless connection to the many other features available in the browser, from speech recognition programming interfaces to in-GPU calculations and calls to external sources of information[4]. From the user side, software does not need to be installed or manually updated, as it is delivered and runs as a regular web page, and it can run on all modern regular consumer devices, except for content specifically developed for high-end XR headsets; even in this case, however, such content is guaranteed by the WebXR standard to work across different AR and VR headsets.

Slowly, educational websites are starting to incorporate WebXR-based AR content that students and teachers can run on their smartphones and tablets. For instance, on certain Google search queries, the results include 3D models (of chemical or biological entities, hardware instruments, and so forth) that users can directly open and see in AR lying on any flat surface around them (thanks to WebXR controlled through Google's model-viewer library). As an example, by searching for 'circulatory system', users can set a very detailed model of the human circulatory system standing right next to them, and then move all around it to inspect its inner structures and organs, much like with the physical models used by medical students. Other 3D content available through Google search includes models of human anatomy, cells, organelles, bacteria, plants, insects, and animals, to name a few.

The above-mentioned access to 3D models is rather limited for concepts on other subjects, particularly chemistry. This subject is however covered by other websites such as BioSIM^{AR} (ref. [5]) and moleculARweb (ref. [6]), which exploit WebXR through the model-viewer library and other web libraries for handling fiducial markers in order to deliver content ranging from general, inorganic, organic and biological chemistry to introductory structural biology. In these websites, users can set views of the objects onto flat surfaces or manipulate molecules and other objects directly in 3D using nothing more than a webcam-enabled device and fiducial markers printed on regular paper. The markers, in this case, give more flexibility for users to handle and interact with the objects in space, allowing them to, for example, test physical interactions between molecules. In fact, moleculARweb includes several modules with interactive content where molecules are not merely static representations, but actually undergo realistic dynamics and interactions.

As far as we know, WebXR has only been applied to the development of educational tools for chemistry and biology, but we are confident that other subjects, such as geometry and physics, would benefit from these immersive experiences. As the technology progresses, it is essential that programmers and educators team up to create and disseminate more content that is relevant for different courses and communities. Ideally, governments should consider fostering this joint work through plans for digital education.

The fact that WebXR-based content can be written to work out of the box in simple consumer devices makes this technology widely available and accessible, as virtually any user with an internet connection and a webcam-enabled device can benefit from it. As a matter of fact, our studies during the COVID-19 pandemic showed that thousands of students were using moleculARweb from their homes, all around the world[6]. Such wide reach should enable an important pedagogical investigation that so far has not been undertaken in detail: beyond allowing more immersive engagement with various types of content, how much do AR and VR actually help students to learn, or educators to convey knowledge? How much faster and better can students learn with these tools? What are the features of AR/VR experiences that make them pedagogically more efficient? What kind of content is needed for future applications? Answering these questions will help shape the future of education, where easily deployable WebXR-based tools could have a central role. ❐

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Author contributions

F.C.R., M.D.P. and L.A.A. discussed the ideas displayed, put together the first manuscript, and revised the subsequent versions.

Competing interests

The authors declare no competing interests.