Virtual and XR Laboratories for Workforce Development
KNOWLEDGE PACK
VIRTUAL and XR LABORATORIES FOR WORKFORCE DEVELOPMENT

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This KP was prepared by Diego Angel-Urdinola, Marjorie Chinen, Gemma Rodon, and Géraldine Perriguey.

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Introduction

What is a KP?

Knowledge Packages (KPs) are short, pragmatic guides on individual topics within EdTech, meant to provide sufficient knowledge and understanding so that non-technical stakeholders can make key planning, design, and procurement decisions when integrating EdTech in education.

They can be used as a starting point for the planning of technology deployment to improve education processes, within education and labor ministries and education institutions.

About this KP

This KP informs decision-makers of the potential of virtual and XR labs to enhance the learning experience of students participating in workforce development programs. These labs can offer students training experiences that are personalized, interactive, hands-on, cost-effective, and up-to-date with industry standards.

The KP compiles information to support the delivery of training programs with a duration of between one-week up to one semester, offered by formal and non-formal TVET institutions, including secondary vocational training centers.

The KP also:

- Provides evidence and case studies showcasing the advantages and results of virtual and XR labs for training.
- Offers guidance on implementation and steps necessary to deploy virtual and XR labs.
- Compiles a catalog of available virtual and XR labs in the market in high-demand sectors, such as auto-mechanics, nursing, and welding.

Operational definition of TVET (Technical and Vocational Education and Training)

Formal TVET (conducive to an academic degree) and non-formal TVET (workforce development and vocational training).

After reading the main content of this KP, some questions might pop*:

- Are there any concerns regarding the effectiveness and usability of virtual and XR labs?
- Are virtual and XR labs an adequate mechanism for instruction in all education fields?
- What methods can be employed to assess and monitor the effectiveness of virtual and XR labs?
- Are virtual and XR labs affordable and cost-effective?

*To know more about these questions and their answers, go to the FAQ available in the annex.
are the main stakeholders?

KPs are designed with a human-centered vision.

Main stakeholders

- **Project Managers**
  - Assist practitioners who lead investment projects and consider using virtual and XR labs to deliver workforce development programs or equipping laboratories and workshops.

- **Policymakers in the Ministries of Education and Labor / Donors / NGOs / social partners**
  - Raise awareness about the pros and cons of using virtual and XR labs for workforce development and inform decisions related to their planning, design, implementation, and procurement.

- **Training Providers and Education Institutions**
  - Provide education institutions (i.e., technical universities, secondary vocational education, vocational training centers) with an overview of the process to implement virtual and XR labs for workforce development, and of lessons learned by education systems that have adopted this technology.
**Problem statement and value proposition**

**Problem Statement and Value Proposition**

**Compared to Traditional Laboratories, Virtual and XR Labs Could Be a Cost-Effective Alternative**

<table>
<thead>
<tr>
<th></th>
<th>‘Traditional’ Laboratories</th>
<th>Virtual and XR Laboratories</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investments</strong></td>
<td>Require large investments for set-up and functioning, including equipment, maintenance, inputs and consumables. Infrastructure depreciates rapidly, requiring periodic updates. Challenging to maintain state-of-the-art technology.</td>
<td>Require less investment in inputs and consumables but more in technical support, licenses, and software updates. Allow for easier adjustments to changes in the industry, facilitating access to up-to-date training and equipment.</td>
</tr>
<tr>
<td><strong>Risks and Safety</strong></td>
<td>Some training situations and learning experiences may be dangerous or difficult to access (e.g., healthcare, welding training, emergency preparedness, mass disasters, etc.).</td>
<td>Reduce potentially expensive and life-endangering risks and allows for practice in a safer environment without pressure or danger.</td>
</tr>
<tr>
<td><strong>Proficiency Development</strong></td>
<td>Limited opportunities to practice, repeat or rehearse due to cost, time, supervision, and space limitations.</td>
<td>Allow for unlimited practice opportunities and can personalize the pace (and scenarios) of the learning experiences in a simulated environment.</td>
</tr>
<tr>
<td><strong>Proficiency Monitoring</strong></td>
<td>Not always capable of monitoring and producing data on student use, performance, and completion of laboratory practices. Teachers are the primary monitoring system.</td>
<td>Facilitate data collection and data analysis, as they automatically register and save data of students’ performance. Also, they generally allow for direct feedback.</td>
</tr>
<tr>
<td><strong>Pedagogy</strong></td>
<td>Teachers are the main source of learning.</td>
<td>Teachers are facilitators, allowing personalized learning based on student performance, preferences, and goals.</td>
</tr>
</tbody>
</table>

**Impact**

When compared to traditional laboratories, students exposed to training in Virtual and XR Laboratories (on average):

- Are up to 30% more efficient using inputs, time, and/or avoiding performance errors, per additional hour of instruction.
- Score 3% higher in technical (cognitive) learning, for each additional hour (¼ hour) of VR training.
- Report on average 30% higher scores in socio-emotional skills assessments after completing their training.

### TYPE OF LABORATORIES

#### WHAT IS A VIRTUAL / XR LAB? SPECTRUM OF OPTIONS

A virtual or XR laboratory is an interactive computer simulation of a laboratory. Its purpose is to give students training opportunities conducive to practical learning for skills development.

<table>
<thead>
<tr>
<th>TAXONOMY</th>
<th>Main features</th>
<th>Effects on learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D-VISUALIZATION IN A 2D SCREEN</td>
<td>3D objects or environments presented in a two-dimensional display, such as a computer screen or a mobile device. Requires input devices such as a keyboard and a mouse for navigating and interacting with software tools. Useful for remote education or when physical access to a laboratory is limited.</td>
<td>Supports acquisition of knowledge. Allows for better understanding of contents.</td>
</tr>
<tr>
<td>3D SEMI-IMMERSIVE / MIXED REALITY</td>
<td>A semi-immersive environment that blends digital 3D content with the user’s real-world environment. The experience is not fully immersive like VR but still offers a heightened sense of presence and interaction with virtual objects. Generally, requires 3D glasses and a specialized equipment in a physical lab.</td>
<td>Supports the development of cognitive and technical skills. Allows to manipulate and interact with objects.</td>
</tr>
<tr>
<td>3D FULLY IMMERSIVE VR</td>
<td>A fully immersive 3D digital environment that allows emulating physical space, movement, and interaction. Users can feel a strong sense of presence in the virtual environment, as if they are physically present within it. Users can interact with virtual equipment, manipulate objects and perform experiments. Typically involves using VR headsets in a physical lab.</td>
<td>Supports the development of cognitive and technical skills. Hands-on practice that enhances muscle memory and emulates real situations at the workplace.</td>
</tr>
</tbody>
</table>

**More immersive experiences associate with higher student engagement, motivation, and learning**
are the potential solutions?

WHAT HAS BEEN DONE IN OTHER COUNTRIES – CASE STUDIES

**Rwanda**
Polytechnic Maintain Engine Course

- **Lab Type:** 3D-visualization in 2D screen.
- **Objective:** maintain and repair engine systems of motor vehicles.
- **Target:** students pursuing a diploma in automobile technology, level 6.
- **Other:** four learning modules (identify engines; maintain the cooling system; service lubrication system; service exhaust system).

**United States and Canada**
International Training Institute (ITI)

- **Lab Type:** wide spectrum of options (VR and 3D simulation technology).
- **Objective:** provide hands-on training to apprentices.
- **Target:** more than 14,000 International Association of Sheet Metal Air, Rail and Transportation Workers (SMART) apprentices.
- **Other:** using Interplay Learning’s technology.

**India**
Virtual Labs project (VLAB) - Video

- **Lab Type:** 3D-visualization in 2D screen.
- **Objective:** provide remote access to labs in various disciplines of science and engineering.
- **Target:** graduate and undergraduate college and university students.
- **Other:** includes web-resources, video-lectures, animated demonstrations, and self-evaluation. Accessible through internet on any PC/laptop or on a smartphone/tablet. No additional infrastructural setup.

- **Labs designed by a consortium of eleven academic institutes, and free to use for everyone.**
- **Local agencies, known as Nodal centers, train centers across India to use the platform, promote usage of virtual labs, and prepare regular reports on platform utilization.**

**Impact** (April 2009 - November 2022): Over 120 Virtual Labs of approximately 700+ web-enabled experiments for remote-operation and viewing. 3,500+ workshops conducted by 1,200+ nodal centers.
Pilot Program to Test Virtual Reality Training Programs for Technological and Technical courses in Higher education.

Financed by the Government of Korea through the Korea World Bank Partnership Facility.

**WHAT**

**are the potential solutions?**

**WHAT HAS BEEN DONE IN OTHER COUNTRIES – ECUADOR**

**Curricula**
- English
- Spanish

**Pedagogical Guide**
- English
- Spanish

**Promo-video**

**Auto Mechanics**
- ActiVaR

**Prevention of Industrial Risks**
- Spanish

**Results & Lessons learned**
- Statistically significant learning gains measured by the percentage increase in the post-test relative to the pre-test.
- Students reported high levels of motivation to continue to learn auto-mechanics, they found it fun and engaging, and they would like to use this technology again.
- Female students are less prone to use technology and participate in group discussions.
- AVR training reported some concerns regarding the usability of technology.

**Meta-Analysis Assessing the Effects of Virtual Reality Training on Student Learning and Skills Development**

**Value Added Evaluation for a Laboratory that Uses Augmented and Virtual Reality to Improve Student Learning in Auto-mechanics**
are the potential solutions?

WHAT HAS BEEN DONE IN OTHER COUNTRIES – NAMSEOUNG UNIVERSITY, KOREA

Glass Department

Lab Type: 3D-visualization in 2D screen.

Objective: create a set of apps to train students to use glass-blowing equipment safely. Uses a zSpace app that instruct students on how to operate a large glass-blowing furnace.

Target: University students.

Impact: Prior to implementing the virtual lab, only 2 students per year were selected to turn equipment on and off as well as conduct maintenance checks. Now, any student who wishes to operate the furnaces participates in the training program and is capable of using the equipment safely after program completion.

Tiling Department

Lab Type: wide spectrum of options (3D-visualization in 2D screen; 3D semi-immersive/ mixed reality (XRs); 3D fully immersive VR).

Objective: creation of three VR applications to allow tiling students to practice tile cutting and installation without waste of resources. The certification pass rates were low (averaging 60%) as compared to above 80% in other fields. This was attributed, in part, to the limited opportunities for students to practice.

Target: University students.

Other: One fully immersive application teaches the overall tile installation process and mirrors the certification exam; two non-immersive applications focus on developing skills, including cutting; mobile prototypes were also created to facilitate home learning.
## WHAT HAS BEEN DONE IN OTHER COUNTRIES – OTHER CASE STUDIES

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>NAME</th>
<th>LAB TYPE</th>
<th>OBJECTIVE</th>
<th>TARGET</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>OpenSTEM Africa</td>
<td>3D-visualization in 2D screen</td>
<td>Improve practical science knowledge</td>
<td>Upper secondary level</td>
<td>Partnership between Open University and Ghana’s MoE</td>
</tr>
<tr>
<td>Morocco</td>
<td>Design and Implementation of a Virtual Laboratory for Physics Subjects in Moroccan Universities</td>
<td>3D-visualization in 2D screen</td>
<td>Develop a low-cost virtual laboratory integrated into an interactive learning environment based on the Moodle platform</td>
<td>First year of Bachelor’s degree students for physics subjects</td>
<td>Use of computer simulation combined with the JavaScript programming language</td>
</tr>
<tr>
<td>Nigeria</td>
<td>StanLab</td>
<td>3D-visualization in 2D screen (lab on a screen, like a movie, but possible to interact. E.g., touch the objects, lift them and put them down on a surface)</td>
<td>Democratize access to quality STEM</td>
<td>Secondary school students</td>
<td>LinkedIn</td>
</tr>
</tbody>
</table>
### WHAT HAS BEEN DONE IN THE PRIVATE SECTOR – CASE STUDIES

<table>
<thead>
<tr>
<th>COMPANIES</th>
<th>BRIEF EXPLANATION</th>
<th>LINKS OF INTEREST</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIRLINES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KLM</td>
<td>VR training ensures the effective use of time and saves costs by keeping aircrafts clear from training. Moreover, pilots can train outside of the classroom or simulator.</td>
<td>Article / Video</td>
</tr>
<tr>
<td><strong>AUTOMOTIVE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMW</td>
<td>AR training for assembly line workers.</td>
<td>Video 1 / Video 2</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>VR simulation for assembly training, such as installing a door or brake.</td>
<td>Article / Video</td>
</tr>
<tr>
<td><strong>LOGISTICS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DHL</td>
<td>VR training to teach employees how to efficiently organize parcels. The technology optimizes the loading process and space as well as reduces CO2 emissions and costs.</td>
<td>Pilot project / Article / Video</td>
</tr>
<tr>
<td>UPS</td>
<td>VR simulations help students practice driving skills, demonstrate their ability to identify and handle driving hazards, as well as improve the efficiency of sorting facilities.</td>
<td>Article / Video</td>
</tr>
<tr>
<td><strong>MEAT PROCESSING</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Australian Meat Processor Corporation (AMPC)</td>
<td>Specialist R&amp;D provider for Australian meat processors. In conjunction with Think Digital, it uses collaborative virtual reality to train their staff. Experiences cover a wide range of industry practices, from dressing appropriately to decontaminating procedures and the operation of equipment.</td>
<td>Article / Video</td>
</tr>
<tr>
<td><strong>WELDING SCHOOLS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Refrigeration School</td>
<td>It uses an innovative VR technology that simulates the experience of welding.</td>
<td>Video</td>
</tr>
<tr>
<td>Tulsa Welding School</td>
<td>It developed OcuWeld, a virtual reality welding training program.</td>
<td>Video 1 / Video 2</td>
</tr>
<tr>
<td><strong>OTHERS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>International Training Institute</td>
<td>VR and 3D-simulation technology to assess, train, and manage skilled trade workers.</td>
<td>Article / Video</td>
</tr>
<tr>
<td>KFC</td>
<td>VR training support for cooks on how to make its chicken better.</td>
<td>Article / Video</td>
</tr>
<tr>
<td>Verizon</td>
<td>VR/AR training help improve operational readiness and enhance the customer experience.</td>
<td>Article / Video</td>
</tr>
<tr>
<td>Walmart</td>
<td>VR training includes multiple scenarios, such as tasks for managers, customer service, sales in stores, or the Black Friday experience.</td>
<td>Article / Video 1 / Video 2</td>
</tr>
</tbody>
</table>
to implement next steps?

DEPLOYMENT PROCESS – DECISION TREE

Is there a laboratory available in the market?

YES

- Mapping course competencies with curricula competencies
- Determine the type of lab
- Software selection (Open source vs. commercial)
- Design of physical space (only if mixed reality/fully immersive)
- Procurement
- Pilot implementation (Short term)
- Monitoring & evaluation
- Implementation at scale (Medium to long term)

NO

- Identification of the training course
- Curricula development
- Determine the type of lab
- Software development (Open source vs. commercial)
- Software selection (Open source vs. commercial)
- Design of physical space (only if mixed reality/fully immersive)
- Procurement
- Pilot implementation (Short term)
- Monitoring & evaluation
- Implementation at scale (Medium to long term)

Integrating software into curriculum and teaching plans, gaining principal buy-in

Teacher training

- Technology
- Pedagogy

Students' instruction on technology

Implementation of the pilot program

Costs and budgeting

Monitoring and evaluation

Deployment process

Catalog
### DEPLOYMENT PROCESS IF LABORATORIES ARE AVAILABLE IN THE MARKET

<table>
<thead>
<tr>
<th>MAPPING COURSE COMPETENCIES</th>
<th>• Align course competencies with curricula competencies. Then, determine the type of lab.</th>
</tr>
</thead>
</table>
| SOFTWARE SELECTION          | • Is the virtual or XR lab cost-effective for training in specific subject area? Creating these educational applications could be laborious and costly, and of low value-added in certain subjects.  
• Does the software exist? Is the software available (open-source or commercial) in the market in the language I need?  
• What is the budget availability?  
• Identify software options in the desired field already in the market (check how much they align to course curricula), and the device requirements. |
| DESIGN OF LABORATORY        | • Minimum technical specifications to ensure satisfactory implementation: space, furniture (“collaborative furniture”), internet connectivity, IT support, human resources, and security. |
| PROCUREMENT                 | • Software/Licenses  
• Laboratory design and equipment (for 3D semi-immersive/ mixed reality (XRs) and fully immersive)  
• Technical support  
• It is recommended to ‘bundle’ procurement in a “service contract” that includes provision of goods and services (licenses, hardware, training of teachers, technical support) |
| IMPLEMENTATION              | • Integrate the content provided through the software into the existing course curriculum and lesson plans.  
• Gain buy-in or operational support from principal.  
• Teacher training on technology and pedagogy: coach teachers on how to use the software as intended in the classroom. Teachers should be willing to change their roles and become facilitators of the learning process instead of being the primary source of information.  
• Instruct students on how to use technology before using the virtual or XR laboratory for instruction. Give special attention to students who are less technology savvy.  
• Technical support to maintain laboratories and help teachers debug technical issues with the labs’ hardware/software.  
• Monitor & Evaluate: establish an information system, indicators, pre-test vs. post-test, and conduct an impact evaluation, if possible. |
**DEPLOYMENT PROCESS IF LABORATORIES ARE NOT AVAILABLE IN THE MARKET**

**IDENTIFICATION OF TRAINING COMPETENCIES**
- Determine whether the subject area of training aligns well with the implementation of a laboratory. Virtual and XR laboratories may not be cost-effective in some fields.
- Identify the competences that would be developed through the implementation of labs.

**TYPE OF LAB**
- Virtual and XR laboratories require minimum technical specifications to ensure satisfactory implementation (space, furniture, internet connectivity, IT support, human resources, and security).
- Select the type of laboratory that best adapts to the course curricula and training needs.

**CURRICULA DEVELOPMENT**
- Develop a competency-based curricula stating clear objectives and competency standards (if possible, aligned with national qualification frameworks or industry certifications).

**SOFTWARE DEVELOPMENT**
- Contact a regional or global firm to start designing the software.
- Envision needs for updates and improvements.
- Decide whether to use open source vs. commercial software.
- It is recommended to ‘bundle’ procurement in a “service contract” that includes provision of goods and services (software development, hardware, training of teachers, technical support, and updates).
**MONITORING AND EVALUATION**

**Theory of Change (ToC)**
- Develop ToC that clearly articulates the causal pathways through which the program operates.
- Use different data collection tools to learn about implementation challenges.
- Collect data on program impacts.

**Program Activities**
1. Virtual or XR laboratory with 3D technology
2. Teacher training: On the use of technology and pedagogy
3. Teacher Pedagogical Manual: With instructions on technology usage, the pedagogical vision, etc.
4. Maintenance: Updates, etc.

**Outputs**
1. Virtual or XR laboratory installed (space, furniture, connectivity)
2. Software functioning as intended
3. Teachers trained
   - Use the technology
   - Implement the pedagogy

**Program Implementation**

**Theory of Change**

**Outcomes**
- Channels to influence student learning:
  - Engagement
  - Motivation to learn
  - Self-efficacy
  - Usability of technology
  - Presence

**Intermediate**
- Survey and student outcome data to assess impacts

**Final**
- Student Learning:
  - Cognitive Skills
  - Technical skills

**Data collection modalities to learn about implementation:**
- Classroom observation
- Interviews with teachers
- Monitoring Survey
- Focus Group Discussions
- WhatsApp Group

**Data collection tools suggested by the literature:**
- Engagement & Motivation
- Self-Efficacy
- Usability
- Presence
ADAPTIVE MONITORING AND EVALUATION

**Iterative Monitoring and Evaluation System to Track the Implementation of the Virtual and XR Laboratory**

**Before implementing at scale**

Conduct a small pilot to identify implementation challenges, program alignment and fidelity, compliance and take up, problems with the use of technology, connectivity, and electricity.

Monitor

1. Implementation of the Pedagogy:
   - Integration to the course curriculum
   - Access and use of the technology
   - The role of the teacher

2. That enabling conditions are in place: equipment, connectivity, electricity, maintenance.

3. Student utilization, learning, motivation, and adaptation to the technology.

**1. Curriculum Implementation**

The curriculum of the virtual or XR lab is implemented.

**Data reported in real time**

**2. Data Collection**

Curriculum is monitored and data collected through the use of semi-structured tools, video recordings and instructor feedback.

**Data analyzed**

**3. Knowledge Generation**

- How activities are implemented.
- What barriers and facilitators exist.
- How activities/processes can be improved/adapted.

**4. Adjustments and Adaptations**

Activities and processes are adapted/improved based on lessons learned to resolve problems.
**Cost Ingredients: Items to Budget**

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Software</strong></td>
<td>• Cost of development of a new software (if lab not available in the market)</td>
</tr>
<tr>
<td></td>
<td>• License costs: Vary based on the number of licenses purchased and their duration.</td>
</tr>
<tr>
<td><strong>Hardware</strong></td>
<td>• PCs / laptops / headsets (type of headsets) / accessories (controllers, speakers, headphones) / import costs (if any)</td>
</tr>
<tr>
<td><strong>Laboratory</strong></td>
<td>• Design of laboratories: Classroom size / connectivity / electricity outlets / furniture / lightning / curtains (for darkness) / tables and chairs / projector / cleaning supplies / bio-safety protocols</td>
</tr>
<tr>
<td><strong>Implementation</strong></td>
<td>• Teacher training (in-person vs. virtual) / student training / data collection and monitoring / technical support (maintenance, updates) / security of the laboratory</td>
</tr>
</tbody>
</table>

*Note: Caveats (concerns regarding the effectiveness and usability of laboratories) included in the Annex*
**BRIEF CATALOG OF POTENTIAL SOFTWARE PROVIDERS: AUTO-MECHANICS**

<table>
<thead>
<tr>
<th>PROVIDER</th>
<th>TYPE OF VIRTUAL / XR LAB</th>
<th>BRIEF DESCRIPTION</th>
<th>RESOURCES/ VIDEOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ActiVaR</td>
<td>3D semi-immersive / mixed reality</td>
<td>Augmented and Virtual Reality (AVR) to deliver training in auto-mechanics. This virtual lab seeks to improve learning of students who are being introduced to the basic principles of the operation of internal combustion engines for the first time. The pedagogical approach includes blended learning modalities.</td>
<td>Video (promo)</td>
</tr>
<tr>
<td>Automotive Mechanic by GTAFA for Zspace</td>
<td>3D semi-immersive / mixed reality</td>
<td>Safely practice the assembly and disassembly of an automobile in a virtual mechanic shop.</td>
<td>Videos <a href="#">here</a></td>
</tr>
<tr>
<td>Electude</td>
<td>3D-Visualization in a 2D screen</td>
<td>Automotive e-learning solutions. Platform that uses gaming technology to teach automotive technology students.</td>
<td>Video about the company</td>
</tr>
<tr>
<td>MIMBUS</td>
<td>3D semi-immersive / mixed reality</td>
<td>SimSpray is a VR solution that helps students master the motion needed to be a successful painter. They learn step-by-step and through practice auto body painting and sandblasting. Niche solution.</td>
<td>Brochure Video of spray-painting demo</td>
</tr>
<tr>
<td>PTC</td>
<td>3D semi-immersive / mixed reality</td>
<td>Use of AR to maximize revenue, reduce costs, and drive efficiency across manufacturing, service, and sales and marketing. The product requires a suite of essential AR apps. It partners with companies like Volvo and Toyota, among others.</td>
<td>Download ‘Use Case Guide’ <a href="#">here</a> Case studies available <a href="#">here</a> (Toyota, Infiniti, Brembo, Volvo) Video on AR</td>
</tr>
<tr>
<td>Uptale</td>
<td>3D semi-immersive / mixed reality and 3D fully immersive VR</td>
<td>Immersive Learning platform to create, share and track. Operational managers can take 360° pictures/videos of the workstations and use them to create realistic and explicit training experiences. These experiences help newcomers visualize their future work environment while getting trained by actively interacting with visually/spatially contextualized information.</td>
<td>Case studies available <a href="#">here</a> (Alstom, DS Smith, Stellantis, Delfingen, etc.) Video (demo) Video (case study)</td>
</tr>
</tbody>
</table>

*Non-exhaustive.*
# INTRODUCTION

**WHY**

**HOW**

**CONCLUSION**

<table>
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<tr>
<th>ANNEXES</th>
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</table>

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## BRIEF CATALOG OF POTENTIAL SOFTWARE PROVIDERS: NURSING

<table>
<thead>
<tr>
<th>PROVIDER</th>
<th>TYPE OF VIRTUAL / XR LAB</th>
<th>BRIEF DESCRIPTION</th>
<th>RESOURCES/ VIDEOS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3D Organon</strong></td>
<td>3D fully immersive VR</td>
<td>3D Organon is a medical &amp; healthcare education platform for teaching and learning anatomy. Shared anatomy learning experiences where students can interact in the same virtual space.</td>
<td>Video (more <a href="#">here</a>)</td>
</tr>
<tr>
<td><strong>Acadius by Arch Virtual</strong></td>
<td>3D-Visualization in a 2D screen, and 3D fully immersive VR</td>
<td>Hands-on clinical training in a safe virtual environment with a high-fidelity simulation. Modes: VR, Non-VR Viewer, or Screen Share.</td>
<td>Demo overview <a href="#">here</a></td>
</tr>
<tr>
<td><strong>Conquer Experience</strong></td>
<td>3D-Visualization in a 2D screen, 3D semi-immersive / mixed reality, and 3D fully immersive VR</td>
<td>Digital Simulation Platform that combines of technical smarts with UX and gamification to create engaging apps and bringing complex scenarios to life. Award winning product: <a href="#">PeriopSim</a> teaches OR nurses instrumentation and procedures before they set foot in the OR.</td>
<td>Case studies <a href="#">here</a> Video (PeriopSim)</td>
</tr>
<tr>
<td><strong>UbiSim</strong></td>
<td>3D fully immersive VR</td>
<td>The World’s First VR Training Platform for Nursing. Learners can practice specific clinical scenarios and receive instant feedback. Pre-built scenarios that can be customized to fit clients’ needs.</td>
<td>Video (VR example) Request case study <a href="#">here</a></td>
</tr>
<tr>
<td><strong>VRpatients</strong></td>
<td>3D-Visualization in a 2D screen, 3D semi-immersive / mixed reality, and 3D fully immersive VR</td>
<td>Virtual Simulation Training for Emergency Responders &amp; Nurses. Access to limitless case scenarios, create content tailored to specific training objectives or use or modify dozens of pre-built cases. Diverse avatars that represent realistic patient population.</td>
<td>Request brochure <a href="#">here</a> Case study <a href="#">here</a> Video (demo)</td>
</tr>
</tbody>
</table>

*Non-exhaustive.*
## BRIEF CATALOG OF POTENTIAL SOFTWARE PROVIDERS: WELDING

<table>
<thead>
<tr>
<th>PROVIDER</th>
<th>TYPE OF VIRTUAL / XR LAB</th>
<th>BRIEF DESCRIPTION</th>
<th>RESOURCES/ VIDEOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fronius</td>
<td>3D-Visualization in a 2D screen, and 3D semi-immersive / mixed reality</td>
<td>Mobile App (here) with training, quizzes and challenges and Welding Simulators (here). The user can practice welding various weld seams in various positions using different workpieces. The simulator software is self-explanatory, easy to use and boasts a sophisticated design and clear menu navigation. Virtual Welding is available in two variants: as a fixed terminal or as a compact carry-case for mobile use.</td>
<td>Brochures available <a href="#">here</a>.</td>
</tr>
<tr>
<td>Lincoln Electric</td>
<td>3D-Visualization in a 2D screen, 3D semi-immersive / mixed reality</td>
<td>VRTEX 360 virtual reality welding trainers for dual users that simulates welding for hands on welding training. It does not require internet connection, only electricity.</td>
<td>Video (company)</td>
</tr>
<tr>
<td>MIMBUS</td>
<td>3D semi-immersive / mixed reality</td>
<td>Designed to teach and evaluate the professional gesture of the welder. It allows learners to perfect the precision of their gestures and their concentration without risking injury and minimizing the risk of breakage or premature wear of equipment. VRTEX 360 Compact is a VR simulator for mobile use in multiple environments to master welding training.</td>
<td>Video (<a href="#">zSpace</a>).</td>
</tr>
</tbody>
</table>

Non-exhaustive.
## BRIEF CATALOG OF POTENTIAL SOFTWARE PROVIDERS: OTHERS

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Aatral</td>
<td>3D-Visualization in 2D screen, 3D semi-immersive / mixed reality and 3D fully immersive VR</td>
<td>AR and VR to enhance production efficiencies, process training, remote assistance, product showcase, troubleshooting, eliminate safety-incidents, increase profitability and become a Smart Factory. Fields: automotive, machinery, defense, energy, aerospace, education, architecture &amp; planning, retail, entertainment.</td>
<td>Case studies <a href="#">here</a>, Videos (products and modules)</td>
</tr>
<tr>
<td>ActiVaR</td>
<td>3D fully immersive VR</td>
<td>VR to prevent industrial risks through immersive scenarios. Contract with Visyon360, specialized in immersive 360 video pieces in monoscopic and stereoscopic formats.</td>
<td>Video / Videos (modules) <a href="#">here</a>⁄3D Digital Twin <a href="#">here</a></td>
</tr>
<tr>
<td>Apprentice</td>
<td>3D semi-immersive / mixed reality</td>
<td>Tempo is a cloud-based platform that works seamlessly across all stages of drug production. It allows resource definitions, master recipes, and production data to be shared instantly. Field: medicine</td>
<td>Video (Tempo)</td>
</tr>
<tr>
<td>Arvizio</td>
<td>3D semi-immersive / mixed reality and 3D fully immersive VR</td>
<td>AR and MR Digital Twins. Fields: healthcare and medical devices, manufacturing, field maintenance, industry 4.0 (engineering and design process), construction, energy, and mining.</td>
<td>Video (Immersive 3D) <a href="#">here</a>, Video (AR instructor)</td>
</tr>
<tr>
<td>CareAR - A Xerox Company</td>
<td>3D semi-immersive / mixed reality</td>
<td>It focuses on improving the service experience while delivering significant operational efficiencies, real business value, and enhanced safety. Sectors: manufacturing, telecom, IT services, and healthcare.</td>
<td>Video (CareAR Assist)</td>
</tr>
<tr>
<td>Cloudberrie</td>
<td>3D fully immersive VR</td>
<td>Adaptive learning platform or turnkey solution to adapt to existing training programs (fire drills, tackle difficult conversations, engine assembly, etc.).</td>
<td>Video (engine assembly)</td>
</tr>
<tr>
<td>Cognitive3D</td>
<td>3D-Visualization in 2D screen</td>
<td>Analytics platform that collects spatial data from immersive experiences, enabling brands to develop better product strategies, and understand consumer behavior. It allows to conduct training situations with clearer results to reduce injury, improve safety, and measure efficiency. Variety of fields.</td>
<td>Pricing options <a href="#">here</a>, Video (Simulated Reality)</td>
</tr>
<tr>
<td>Dimenco</td>
<td>3D semi-immersive / mixed reality</td>
<td>Simulated Reality (SR) technology that delivers 3D experiences without the need for glasses. Variety of fields.</td>
<td>Video (what is SR?) Video (Simulated Reality)</td>
</tr>
<tr>
<td>Embodied Labs</td>
<td>3D fully immersive VR</td>
<td>Immersive training for healthier aging to embody the perspectives and conditions of others. It empowers more effective, empathetic care for patients, customers and family members. Fields: senior services, academic programs, local government, corporate partners, homebased care.</td>
<td>Video (overview) Video (Alzheimer’s)</td>
</tr>
<tr>
<td>EXXAR</td>
<td>3D-Visualization in 2D screen, 3D semi-immersive / mixed reality, and 3D fully immersive VR</td>
<td>VR/AR for training, allowing for virtual collaboration, design reviews and training. The platform can be used in different devices (VR, AR, MX, desktop). Fields: construction, industrial, manufacturing.</td>
<td>Videos <a href="#">here</a></td>
</tr>
<tr>
<td>Festo Didactic</td>
<td>3D-Visualization in 2D screen</td>
<td>Holistic solutions and equipment for all areas of technology in factory and process automation, such as pneumatics, hydraulics, engineering, production, mechatronics, and telecommunications.</td>
<td>Brochures and Catalogues <a href="#">here</a>, Video / Video (software)</td>
</tr>
</tbody>
</table>

Non-exhaustive.
## BRIEF CATALOG OF POTENTIAL SOFTWARE PROVIDERS: OTHERS

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<tbody>
<tr>
<td>Holo-Light</td>
<td>3D semi-immersive / mixed reality, and 3D fully immersive VR</td>
<td>AR and MR to speed up product development (prototyping, design reviews, factory simulation, immersive trainings). <em>Sectors:</em> automotive, mechanical engineering, aerospace &amp; defense.</td>
<td>Case studies [here Video (XR)] / [Video (AR)]</td>
</tr>
<tr>
<td>Immerse.io</td>
<td>3D-Visualization in 2D screen, 3D semi-immersive / mixed reality, and 3D fully immersive VR</td>
<td>Content aggregation, distribution and reporting platform that utilizes an enterprise-grade cloud service for management, deployment and reporting of collaborative VR training applications. <em>Variety of fields.</em></td>
<td>Case studies [here Video]</td>
</tr>
<tr>
<td>Innoactive</td>
<td>3D semi-immersive / mixed reality, and 3D fully immersive VR</td>
<td>Enterprise XR CMS with cloud streaming for training and visualization. Technology used by large enterprises to deploy VR training to employees, customers and suppliers. <em>Variety of fields.</em></td>
<td>Pricing options <a href="demo">here Video</a></td>
</tr>
<tr>
<td>Interplay Learning</td>
<td>3D-Visualization in 2D screen, 3D semi-immersive / mixed reality, and 3D fully immersive VR</td>
<td>VR training provider in skilled trades to create job-ready skilled trade workers faster and easier. <em>Fields:</em> HVAC, plumbing, electrical, multi-family and facilities maintenance, safety, solar, electrical, and hospitality.</td>
<td>Video / Video 2</td>
</tr>
<tr>
<td>iQ3Connect</td>
<td>3D semi-immersive / mixed reality, and 3D fully immersive VR</td>
<td>Real-time 3D spatial training and collaboration. It offers instant VR experiences, allowing access to immersive experiences and VR workspaces. <em>Variety of fields.</em></td>
<td>Video</td>
</tr>
<tr>
<td>LabTech</td>
<td>3D-Visualization in 2D screen, and 3D semi-immersive / mixed reality</td>
<td>TVET systems designer and manufacturer that aims to provide 21st century skills infused technical and engineering learning solutions for TVET schools, polytechnics, and universities. <em>Sector:</em> education.</td>
<td>Video</td>
</tr>
<tr>
<td>Metadome</td>
<td>3D-Visualization in 2D screen, and 3D semi-immersive / mixed reality</td>
<td>Solutions for creating and deploying XR experiences at scale. If offers <a href="https://www.autodome.co">Autodome</a>, an immersive automotive platform for 3D and XR applications. <em>Variety of fields,</em> including automotive, home decor, fashion, cosmetics, and accessories.</td>
<td>Video</td>
</tr>
<tr>
<td>Sim Insights</td>
<td>3D semi-immersive / mixed reality and 3D fully immersive VR</td>
<td>AR/VR/AI cloud-based SaaS software and services to transform training and operations with immersive, interactive and personalized (AI-powered) training content. It also offers <a href="https://www.hyperskill.org">HyperSkill</a>, an innovative tool to author, publish and evaluate AI-powered training content. <em>Fields:</em> healthcare, manufacturing, education, retail, etc.</td>
<td>Pricing <a href="simulation">here Video</a></td>
</tr>
<tr>
<td>Talespin</td>
<td>3D fully immersive VR</td>
<td>Immersive learning for the future of work. It helps use XR to learn faster, validate skills, and find upward mobility in the workforce. <em>Fields:</em> leadership, healthcare, insurance training, etc.</td>
<td>Video</td>
</tr>
<tr>
<td>VRdirect</td>
<td>3D-Visualization in 2D screen and 3D semi-immersive / mixed reality, and 3D fully immersive VR</td>
<td>VR platform that enables enterprises to create use case-driven VR solutions that support real-life business processes and deliver concrete business value. <em>Variety of fields.</em></td>
<td>Client examples [here Video]</td>
</tr>
<tr>
<td>VSight</td>
<td>3D-Visualization in 2D screen, and 3D semi-immersive / mixed reality</td>
<td>Increase operational efficiency and expert utilization as well as empower frontline workers with interactive digital instructions (solve mechanical problems, monitor assembly lines). <em>Fields:</em> machinery and equipment, manufacturing, mining, healthcare, construction.</td>
<td>Case studies [here Video]</td>
</tr>
</tbody>
</table>

*Non-exhaustive.*
Conclusion

**WHO**
This KP can effectively support project managers, policymakers in the Ministries of Education and Labor, donors, NGOs, social partners, training providers, and education to enhance student's learning experience in workforce development programs by implementing virtual and XR laboratories.

**WHAT**
There exist different types of virtual and XR laboratories (3D-Visualization in 2D screen; 3D semi-immersive/mixed reality (XRs); 3D fully immersive), with varying effects on learning. More immersive experiences are linked with higher student engagement, motivation, and learning. Several countries, such as Ecuador, Korea, Rwanda, India, and the private sector, are already using this technology to enhance workforce development training programs.

**WHY**
Virtual and XR labs could be a cost-effective alternative to traditional laboratories in terms of investments, risks and safety, proficiency development and mentoring, and pedagogy. Moreover, virtual and XR labs can potentially accelerate students’ learning curve and provide significant learning gains.

**HOW**
The deployment process is contingent upon the market availability of the software (on whether it has been developed or not). Before integrating the technology into the course curricula, it is essential to ensure the software and hardware are reliable. Costs vary greatly, depending on software, hardware, laboratory, and implementation. A wide range of software providers exists in the market in many different fields, including auto-mechanics, nursing, and welding.
To go further

CLOUD OF KPs

OTHER EXISTING RELATED KPs

- LMS
- Assessment
- Procurement
- Digital content
- Teachers’ competencies

RELATED SOURCES

Podcast: Employing Virtual and XR Laboratories for Workplace Development

STAY CONNECTED

- Follow us on Twitter
- Spotify & Anchor: Subscribe to our podcast channel
- More updates on Medium
- Subscribe to our Skills GSG Newsletter
- Skills Global Solutions Group website
Annexes

GLOSSARY

Operational definition of TVET:
Technical and Vocational Education and Training. Formal (conducive to an academic degree) and non-formal TVET (workforce development and vocational training).

Virtual and XR Laboratories:
Interactive computer simulation of a laboratory. Its purpose is to give students training opportunities conducive to practical learning for skills development.

3D-Visualization in a 2D Screen:
3D objects or environments presented in a two-dimensional display, such as a computer screen or a mobile device. Requires input devices such as a keyboard and a mouse for navigating and interacting with software tools. Useful for remote education or when physical access to a laboratory is limited.

3D semi-immersive/ mixed reality:
A semi-immersive environment that blends digital 3D content with the user’s real-world environment. The experience is not fully immersive like VR but still offers a heightened sense of presence and interaction with virtual objects. Generally, requires 3D glasses and a specialized equipment in a physical lab.

3D fully immersive VR:
A fully immersive 3D digital environment that allows emulating physical space, movement, and interaction. Users can feel a strong sense of presence in the virtual environment, as if they are physically present within it. Users can interact with virtual equipment, manipulate objects and perform experiments. Typically involves using VR headsets in a physical lab.

XRs:
An umbrella term that encompasses various extended reality technologies, including virtual reality (VR), augmented reality (AR), and mixed reality (MR).

Quest:
The most used VR headset for education. It doesn’t require to be connected to a computer/laptop.
Annexes

REFERENCES AND LINKS OF INTEREST

- Building Better Formal TVET Systems - Principles and Practice in Low- and Middle-income Countries
  http://documents.worldbank.org/curated/en/099071123130516870/P175566037a3e20650a657068b5152205bf

- Digital Skills Development in TVET teacher training
  https://files.eric.ed.gov/fulltext/ED619368.pdf?deliveryName=DM170416

- Key considerations on Technical and Vocational Education and Training (TVET)
  https://www.unhcr.org/5c628dc04.pdf

- Meta-Analysis Assessing the Effects of Virtual Reality Training on Student Learning and Skills Development

- Promoting quality in TVET using technology

- The Digitization of TVET and Skills Systems

- Transforming Technical and Vocational Education and Training for successful and just transitions
  https://unesdoc.unesco.org/ark:/48223/pf0000383360?deliveryName=DM170416

- Unleashing the Power of Educational Technology in TVET Systems

- Value Added Evaluation for a Laboratory that Uses Augmented and Virtual Reality to Improve Student Learning in Auto-mechanics
  http://documents1.worldbank.org/curated/en/099000002142331490/pdf/P16785402b53050d0a0bf015392e9bd55b.pdf

- Can VR training save lives?

- Can Virtual Reality simulators develop students’ skills?

- COVID-19 highlights the urgency of TVET reforms
Annexes

FAQs

• Are there any concerns regarding the effectiveness and usability of virtual and XR labs?

• Are virtual and XR labs an adequate mechanism for instruction in all education fields?

• What methods can be employed to access and monitor the effectiveness of virtual and XR labs?

• Are virtual and XR labs affordable and cost-effective?
### Annexes

**Are there any concerns regarding the effectiveness and usability of virtual and XR labs? – Caveats**

<table>
<thead>
<tr>
<th>Caveats</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connectivity</td>
<td>Reliable and robust internet connection is required to download the solution and/or to use the platform effectively. It is essential for institutions to assess their capability in this regard beforehand. For instance, some applications can be used offline and internet connection may not always be necessary.</td>
</tr>
<tr>
<td>Data Privacy</td>
<td>AR/VR raise new concerns regarding user privacy due to the scope, scale, and sensitivity of the personal data involved.</td>
</tr>
<tr>
<td>Hygiene (*)</td>
<td>It is important to assess the capacity of the technology to accommodate multiple users simultaneously. Also, maintaining proper hygiene is crucial due to shared equipment, contact with face, eye health, allergies and sensitivities, and health and safety compliance. You may find some best practices <a href="#">here</a>.</td>
</tr>
<tr>
<td>Information Overload (*)</td>
<td>Avoid including more elements than necessary to the software experience, as it may expose students to visual distractions and hinder learning (e.g., do not include animations that don’t contribute to learning).</td>
</tr>
<tr>
<td>Sickness (*)</td>
<td>AR/VR can sometimes induce motion sickness due to a phenomenon known as “simulator sickness” or “cybersickness”. It is important for users to take breaks, gradually adjust to the technology, and discontinue use if they experience discomfort.</td>
</tr>
<tr>
<td>Optical Eyeglasses (*)</td>
<td>AR/VR need to be accessible, safe, and comfortable for every students, including those who wear glasses. Consider buying clippers or spacers that facilitate the use of the equipment among students with glasses.</td>
</tr>
<tr>
<td>Resistance to Change</td>
<td>Teachers play an essential role for implementing AR/VR in education, but they can sometimes be resistant to implement this technologies due to lack of familiarity, limited training and professional development, curriculum alignment and technical challenges. Make sure teachers are involved in the process and properly trained.</td>
</tr>
</tbody>
</table>

(*) Only apply to 3D semi-immersive / mixed reality (XRs) and fully immersive VR
Are virtual labs and XR labs an adequate mechanism for instruction in all education fields? What methods can be employed to access and monitor the effectiveness of virtual and XR labs?

Virtual and XR labs may not be universally applicable across all educational disciplines. While they can be highly beneficial, VR training has the potential to overwhelm students with excessive information, diverting their attention from the essential aspects of the curriculum. However, virtual and XR labs can be particularly advantageous for subjects that necessitate visualizing learning materials in three dimensions. It is crucial to recognize that technologies alone do not facilitate learning; rather, they provide experiences that, in turn, can foster the learning process.

Are virtual and XR labs affordable and cost-effective?

Costs of virtual and XR labs vary significantly, and there are affordable options in the market. Governments may promote the development and adoption of open-source software to provide access to virtual and XR labs (3D-Visualization in 2D screen). India and Rwanda are examples of countries that have taken these initiatives.

Regulation is also emerging to promote the use of virtual and XR laboratories. An approach is to award grants to SMEs and education institutions to conduct immersive technology education and workforce training programs or career pathways that use immersive technology. This is the case of the bill proposed in the U.S. Congress (H.R.9674 - Immersive Technology for the American Workforce Act of 2022) in December 2022. This legislation seeks to facilitate the provision of financial resources to colleges, educational institutions, and other workforce training programs, enabling them to incorporate augmented, virtual, and mixed reality devices into their training initiatives for both current and prospective workforce development.

Virtual and XR labs labs can be costly to set up and maintain. Failure to invest in keeping the technology up-to-date can result in diminished educational outcomes and limited impact on student learning. Virtual and XR labs often require continuous investments to ensure that the technology remains up to date. Without regular updates, the impact may be minimal or even negligible. Therefore, institutions must be prepared to allocate sufficient resources not only for the initial implementation, but also for ongoing maintenance and updates to maximize the effectiveness of virtual and XR labs.

In addition, in some cases other technologies may be more cost-effective. Alternative digital tools such as videos, interactive games, and online tests could provide engaging and interactive learning experiences to students when VR/AR technology is not feasible due to budget constraints.
Supported with funding from

- World Bank Group
- Skills Global Solutions Group
- Digital Development Partnership
- Korea-World Bank Partnership Facility