15 Years of VR/AR in Education
A Personal Summary and Outlook

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Overview

- A Brief Personal History
  - Construct3D & Evaluations
  - PhysicsPlayground

- Challenges for Use in Mainstream Education

- Outlook
  - Augmented Reality in Education
  - Virtual Reality in Education
Early Work

• Zengo Sayu (Rose H. et al., 1995)
• ScienceSpace (Dede C. et al., 1996)
• NICE (Roussos M. et al., 1999)
• CyberMath (Taxen et al., 2000)

AR Education:
• MagicBook (Billinghurst et al., 2001)
Construct3D
(since 2000)
Features

• Points, 2D primitives
• Basic 3D objects
• Intersections
• Boolean operations
• Normal, tangent, tangential plane
• B-Spline curves, NURBS-surfaces
• Surfaces of revolution
• Sweep surface, translation surface
• Transformations, measurements...
• Differential geometric objects

Dynamic modifications of points are possible at all times!
Interaction Devices

Pen & Tablet
2d

Opens the 2d Menu - actions in this menu require that objects be selected first.

- 16 students (age 16-19) working in teams of two
- One teacher supervises each team
- 5 training sessions
- Basic dual-user evaluation setup
- ISONORM 9241 Usability questionnaire

Summary in [2], HCI 2007, LNCS Springer
Milling Cutter

Given: Surface of revolution
Find diameter of spherical cutting tool
Main Results

Construct3D is

- Easy to use, requires little time to learn
- Encourages learners to try new functions
- Can be used consistently
  - Designed in a way that things you learned once are memorized well
Key Strengths

- Dynamic 3D geometry - nearly haptic interaction with geometric objects
- Students can walk around objects. Active relationship between body – object
- Strength to visualize abstract problems

**Ideal content:** Highly dynamic examples which encourage modifications and visualize abstract problems
PhysicsPlayground

• Basic building blocks:
  • 3D shapes / actors
  • Joints
  • Interaction adapters
    • Force adapter
    • Analyzer adapter
• Simulation mode
• System control (load/save)
Physics Playground - Analyzer

• Allows to monitor physical behavior and properties
  • Real time logging
  • Multiple connections between adapters and analyzer inputs possible
Teaching content – Torque

- Flywheel is spinned by exerting force on the handle
- Torque depends on length of handle
  - longer handle, larger torque
- Friction causes deceleration: exponential factor
Teaching content - Crankshaft

- Piston is moved by exerting force on flywheel
- Motion of the piston is analyzed
  - Path of movement is recorded
  - Analyzer shows acceleration and deceleration
  - Rotational motion transforms into sinus wave
Findings

• Simulation very robust for experiments with rigid bodies
• Accuracy of the Nvidia PhysX engine is sufficient for educational purposes
• Variety of teaching content
• Very motivating for students
• Real time simulation and monitoring of experiments possible
Constructivist Theory

• Knowledge is actively built by learners
  PhysicsPlayground: Active construction, real time simulation

• Knowledge construction (learning) is a collaborative process
  PhysicsPlayground: Collaborative Learning in AR

• Learning is contextual
  Adaption of old knowledge to new experience - integrate known types of information

• Motivation is a key component

• Support different learning styles/modes
Challenges:
Why is it not used in schools yet?

Proof of VR/AR’s effectiveness is difficult!

1. Didactical Aspects
2. Organizational Aspects
Didactical Aspects

- Teaching in AR/VR very similar to current computer-supported teaching.
- Tasks needed that actually engage learners and require their active involvement.
- Teaching in smaller groups.
Variety of Hardware Setups

Stereo Projection (EON Reality)

Wii Controller + Auto-stereoscopic screen

Projection Environment (EON Reality)
Multi-User Support

- 6 wireless HMDs attached to one consumer graphics card (using TripleHead2Go)
- Rendering 6 stereo views on 1 PC; interactive frame rates
- Private screen + private view for each user
- Personalized output: Context-sensitive views

in International Journal of Virtual Reality, 2007
Didactical Aspects

• Teaching in AR/VR very similar to current computer-supported teaching
• Tasks needed that actually engage learners and require their active involvement.
• Teaching in smaller groups
• Time needed for adjustment and adaptation of teaching material
• Lack of ICT-competence of teachers
Organizational Aspects

- Access to infrastructure
- Ease of use of AR/VR infrastructure
- Costs !!! - missing financial means
  - Hardware & Software
  - Maintenance / Repair ?
- Sponsoring of companies could be an option

1 PC w high-end graphics card ~2.500 EUR
1 Head mounted display ~5.000 EUR
1 wireless pen ~1.000 EUR
1 Plexiglas tablet ~10 EUR
1 optical tracking system ~50.000 EUR

~58.510 EUR
iTracker
affordable infrared-optical pose tracking

IEEE Virtual Reality 2007
VR 2007
March 10-14, 2007 Charlotte, North Carolina USA

Specifications

Update rate: 60 Hz
Latency: 18 - 40 ms
Jitter: < 0.05 mm / 0.02°
## Costs of an Immersive HW Setup (2007)

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 PC with high-end graphics card</td>
<td>~1.500</td>
</tr>
<tr>
<td>1 Head mounted display</td>
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</tr>
<tr>
<td>1 Plexiglas tablet</td>
<td>~10</td>
</tr>
<tr>
<td>1 optical tracking system</td>
<td>~11,000</td>
</tr>
</tbody>
</table>

In 2003: ~58,510 EUR  
In 2007: ~14,040 EUR

→ Successful change of the market situation
State of the Art & Outlook: Augmented Reality in Education
Use of Available Hardware in Schools
Interactive Books

Re-writeable holographic Display

BooksComeAlive.co.uk
New AR Devices Coming...

- Spaceglasses (Jan 2014)
- Cast AR (Sep. 2014)
State of the Art & Outlook: Virtual Reality in Education
Why don‘t we turn movie theaters into VR learning environments in the mornings?
Costs of an Immersive HW Setup (2013)

in 2007: ~14.040 EUR
Oculus Rift

- Stereoscopic
- Large FOV: 110° diagonal
  90° horizontal
- Weight: 220 grams
- Resolution (HD version): 960x1080 per eye
- Price ~300 USD
- The best existing low cost immersive HMD
Sony MOVE
Motion Controller

• Inertial sensor – measures orientation (gyroscope, accelerometer, magnetometer)
• 60 Hz camera used for optical tracking of colored sphere
  – High accuracy (cm/mm)
  – Controller can change colors (eases segmentation)
New Immersive Setup: Oculus Rift + PS Move Controller used for Tracking
Costs of an Immersive HW Setup (2013)

1 PC with good graphics card  ~1.500 EUR
1 Oculus Rift head mounted displays  ~300 EUR
1 Razer Hydra Controller  ~150 EUR
1 PSMove for optical tracking  ~50 EUR

in 2003:  ~58.510 EUR  in 2013:  ~2.000 EUR

Prototype, no professional maintenance.
Nobody uses such a VR setup for education yet.
The Future of Immersive VR in Education
Walking through all these places in one day?
Flexible Spaces

- Real world rules do **not** apply
- Real walking
- Natural constraints
- Focus on virtual content
- Bigger distance between the rooms – more overlap
- Procedural layout generation
Summary

- Content development expensive & time consuming
- Organizational issues remain
- Technological advances lower costs!
  - New display technologies
  - Flexible input devices
  - Work in small and large groups possible, depending on hardware setup
- Content can be taught differently (in 3D)
  - New teaching material can be taught
- VR/AR: High potential for teaching & learning
Thank you!

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