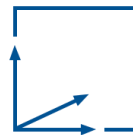


# Evaluation of an Augmented-Reality-based 3D User Interface to Enhance the 3D-Understanding of Molecular Chemistry

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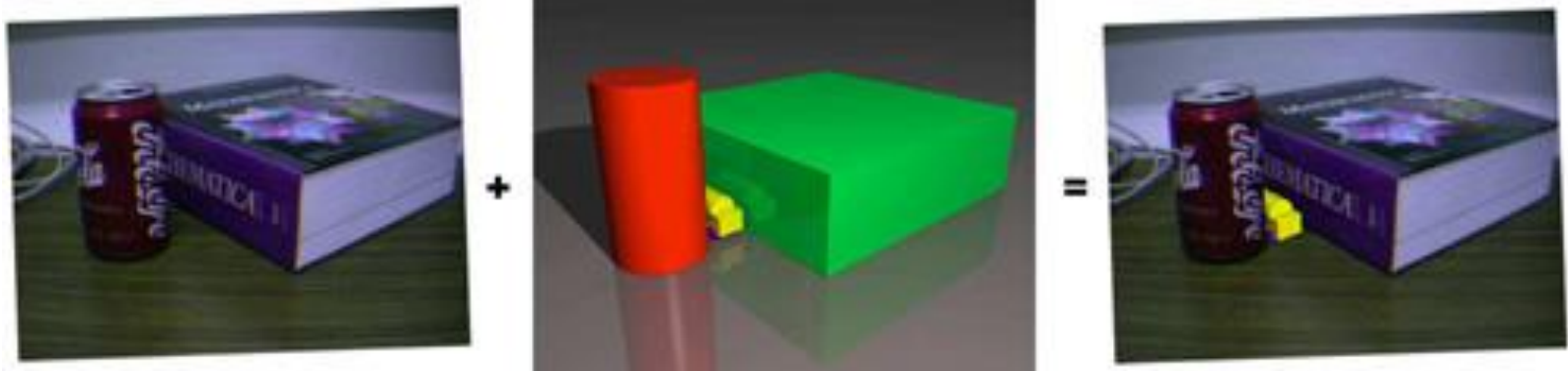


# Overview

- Augmented Reality
- Augmented Chemical Reactions
- Help in Education / Teaching Chemistry
- Evaluation at German Gymnasium
- Results from the Evaluation

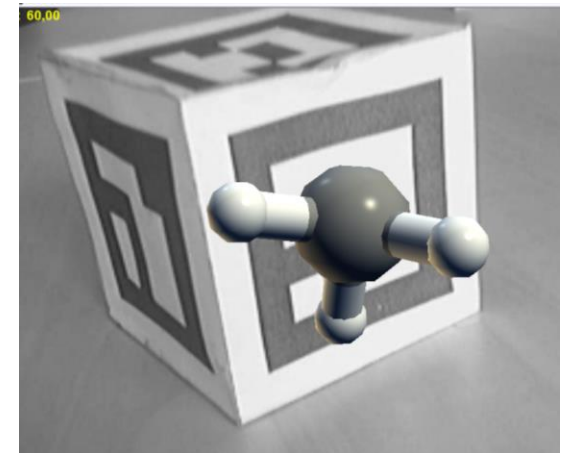
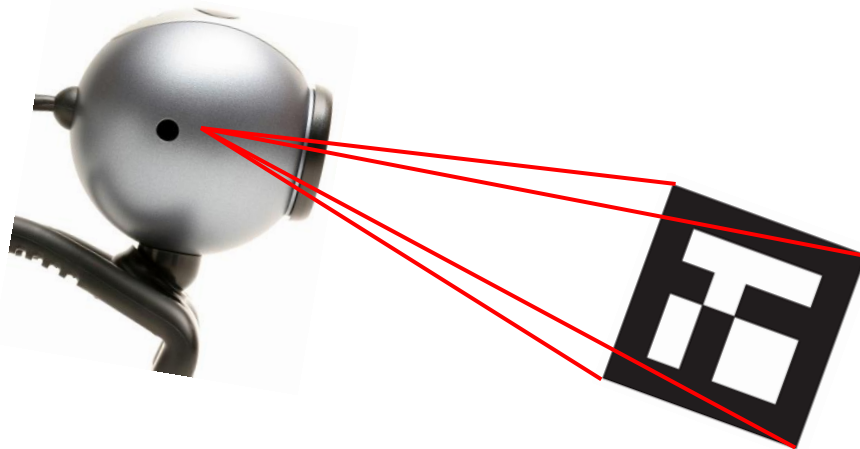
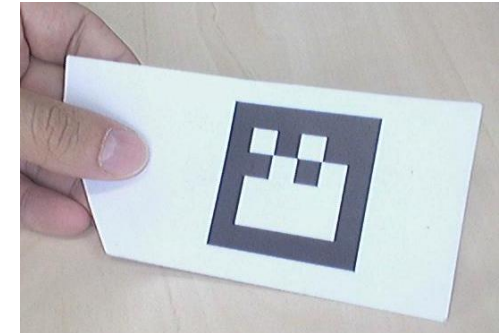
# Augmented Reality Technique

- Real + Virtual
- Interactive in real-time
- Registered in 3 Dimensions



# Augmented Reality - Technology

- Manipulation of real objects (markers)
- Webcam takes picture of the markers
- Calculating the position and orientation of the markers
- Augment the picture with virtual objects





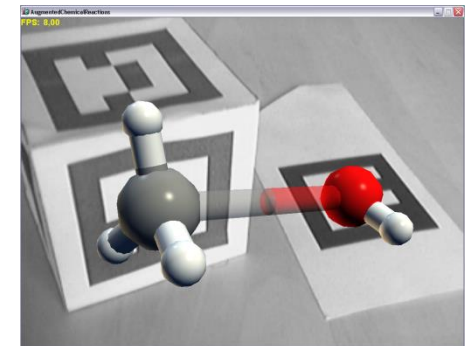
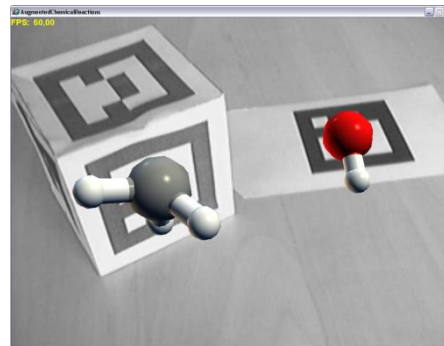
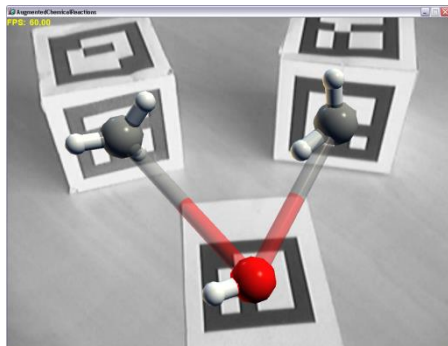
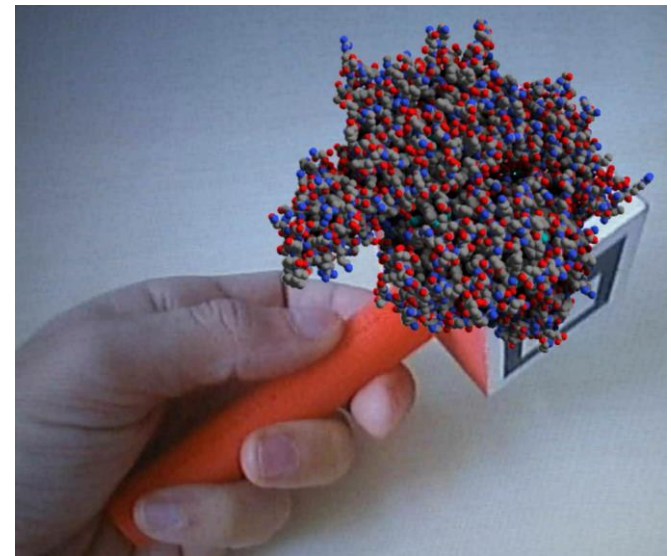
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# Augmented Chemical Reactions

## Augmented Reality for Chemistry

- Inspect molecules intuitively
- Help to understand
- Help to design molecules
- Show the dynamics
- Tangible molecules/reactions





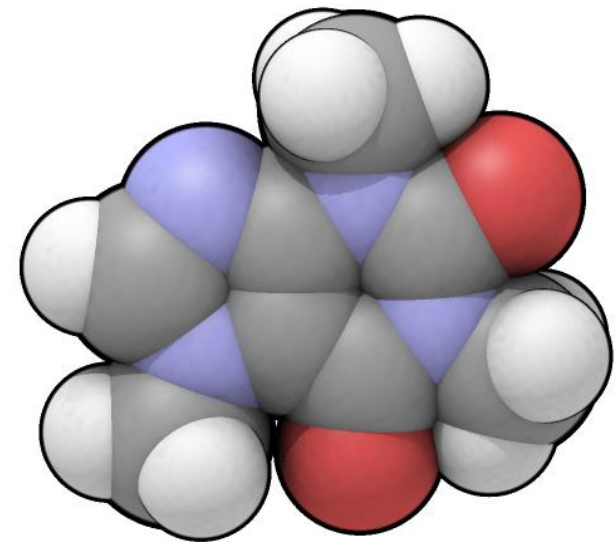
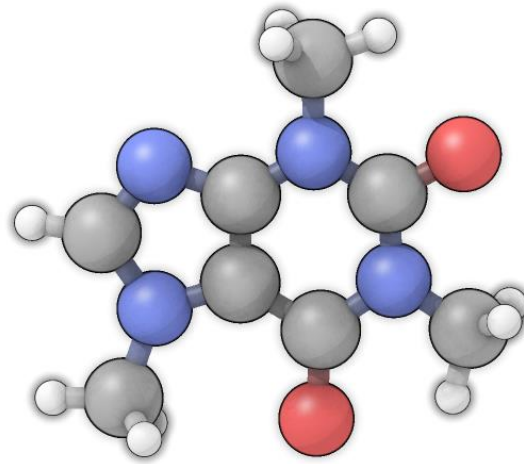
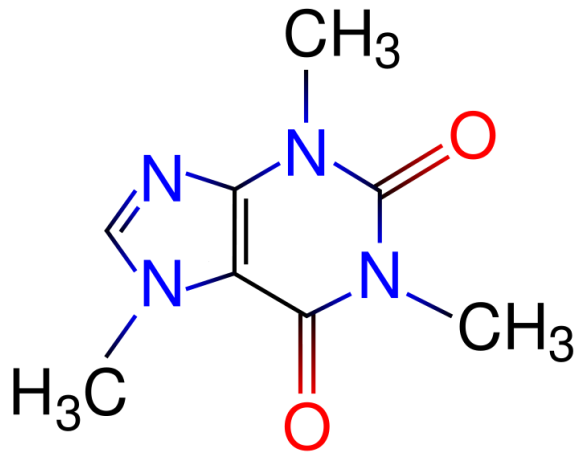
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# Help in Education / Teaching Chemistry

Help to understand:

- Educational help
- Improve 3D understanding of molecules
- Inspect molecules in an intuitive way



Caffeine:  $C_8H_{10}N_4O_2$





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# Evaluation at German Gymnasium

**Question:**

**Does Direct Manipulation Help?**

# Evaluation: Setup

- 13 Students aged 14-15 (8<sup>th</sup> grade Gymnasium)
- Compare:
  - Augmented Chemical Reactions (ACR) (Direct 3D User Interface)
  - Jmol (Mouse, Keyboard Interaction)
- 10 different Molecules

Sulfur  $S_8$ , Methane  $CH_4$ , Ethanol  $C_2H_5OH$ , Acetic acid  $C_2H_4O_2$ , Benzene  $C_6H_6$ , Hydrogen sulfide  $H_2S$ , Phosphor  $P_4$ , Phosphorus trisulfide  $PF_3$ , Hexane  $C_6H_{14}$ , Carbon tetrabromide  $CBr_4$
- 2 Computer Rooms

# Evaluation: Room ACR

- ACR Application
- Webcam on Microphone stand
- Marker Handle



# Evaluation: Room Jmol

- Jmol Application
- Keyboard and Mouse





# Evaluation: Tasks

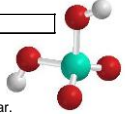
1. Short Introduction
2. Fill out Exercise Sheet
3. Build Clay Models
4. Use Applications
5. Refine Clay Models
6. Choose Correct Molecules



# Evaluation: Check Knowledge

8. Klasse Chemie NTG	AB Moleküle 3D	Name:
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**MOLEKÜLE 3D**



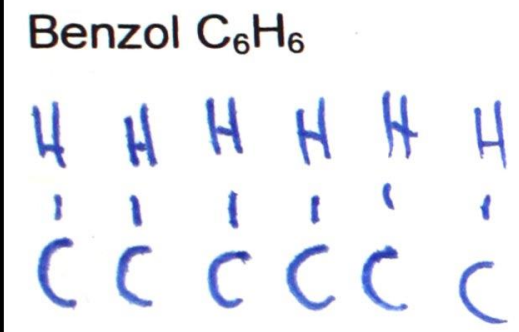
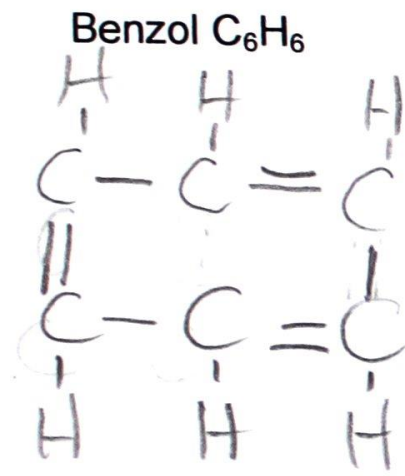
1. Stelle die folgenden Moleküle in Valenzstrichschreibweise (LEWIS-Formel) dar.

Schwefel S <sub>8</sub>	Methan CH <sub>4</sub>
Ethanol C <sub>2</sub> H <sub>5</sub> OH	Essigsäure C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>
Benzol C <sub>6</sub> H <sub>6</sub>	Schwefelwasserstoff H <sub>2</sub> S
Phosphor P <sub>4</sub>	Phosphortrifluorid PF <sub>3</sub>
Hexan C <sub>6</sub> H <sub>14</sub>	Kohlenstofftetrabromid

2. Baue die Moleküle mit Hilfe von Knetmasse und Zahnstochern nach. Achte dabei besonders auf die **räumliche Struktur** der Moleküle!

3. Betrachte die oben genannten Moleküle mit Hilfe des dargebotenen Computerprogramms.

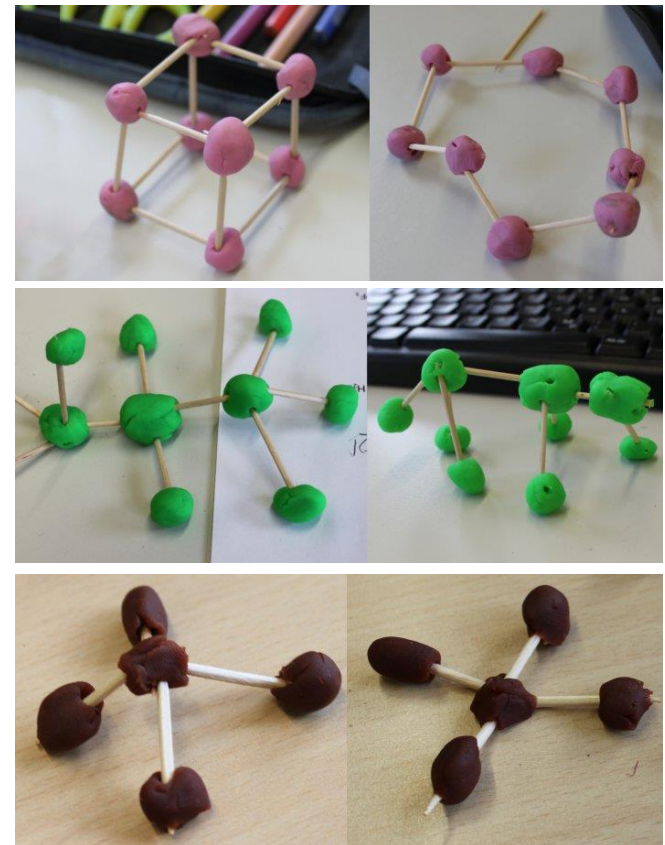
4. Überprüfe deine zuvor erstellten Molekülmodelle und verbessere diese gegebenenfalls.



# Evaluation: Measure Improvements

Compare Clay Models BEFORE and AFTER the use of the Application.

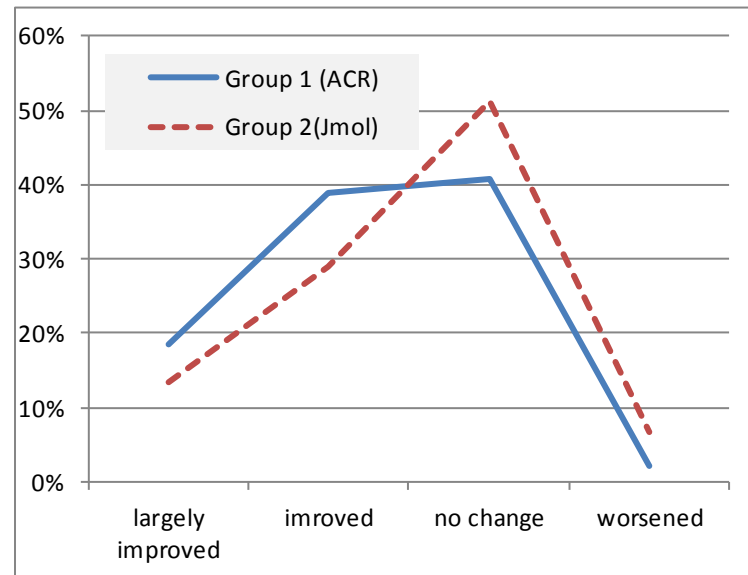
- Large Improvement (2 Points)
- Normal Improvement (1 Point)
- No Improvement (0 Points)
- Worsened (-1 Point)





# Results of Clay Molecule Improvements

- ACR (direct manipulation) significant better than Jmol (mouse, keyboard)
- More improvements with the ACR Group than with the Jmol Group



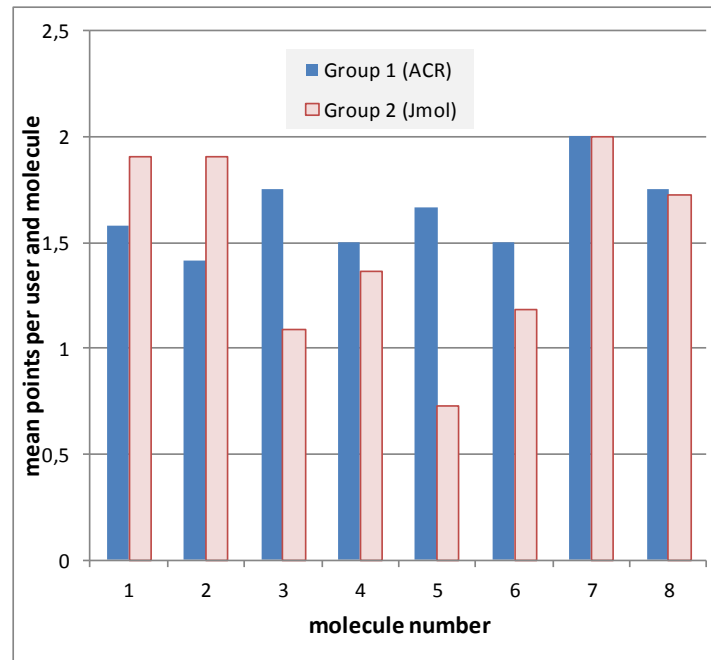
# Evaluation: Choose correct Molecule

- Table with prebuilt Clay Molecules
- 2-3 Versions of 8 Molecules
- Correct Version (2 Points), Nearly Correct (1 Point), Wrong (0 Points)



# Results of Picking the correct Version

- Interesting: Group ACR worse in first two Molecules
- Possible cheating (?) of Jmol on the first two Molecules





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- Discussion



# Discussion

## Significant Improvement

Direct manipulation leads to a better spatial understanding  
Mouse and keyboard results in mental distraction from the  
molecular shape

Students had fun using the tool  
Like to use it in class

Further investigation with a longer period has to be done

# Thank you :-)



[Demo](#) [Video](#)