Julius-Maximilians-
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CoTeach

The impact of using multimedia technology in learning conceptual electrical knowledge

Comparing a traditional approach with the use of an AR-application and a simulation regarding their capability to support learning in a student laboratory

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GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

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Theoretical Background

Starting point of the project

Misconceptions regarding basic electrical concepts are prevalent and have been found…

→ after the introductory lessons regarding simple circuits. *(Burde, 2018; Ivanjek et al., 2021)*

→ after finishing early secondary school. *(Müller et al., 2015)*

→ among first-semester students of physics. *(Fromme, 2018)*

Assumption: The complexity of the content presented is high and cognitively challenges students (too much). *(Burde et al., 2020)*

Cognitive Theory of Multimedia Learning *(Mayer, 2014)*

Approach: Reducing the cognitive challenge using…

→ Spatial and Temporal Contiguity Principle *(Mayer et al., 2014)*

→ Segmenting Principle and Coherence Principle *(Mayer et al., 2010)*

Two thematic blocks in learning about electricity could benefit:

→ *Learning about and with models* *(Burde et al., 2020)*

→ *Data acquisition* *(Kapp et al., 2021)*

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Research Interest and Design

Research Interest

1. What impact does **digital support for model presentation** have on **learning** (in terms of Conceptual Knowledge Gain and Time on Task) and **cognitive load**?

2. What impact does **digital support for data acquisition** have on **learning** (in terms of Conceptual Knowledge Gain and Time on Task) and **cognitive load**?

Gathered Data and used Test Instruments

→ Conceptual Knowledge Test *(Ivanjek et al., 2021)*, Time on Task, Cognitive Load Scale *(Klepsch et al., 2017)*

→ Level of academic achievement (in form of school grades), Affinity for technology *(Karrer et al., 2009)*, Spatial Visualization Ability *(Heller et al., 2000)*

	Measuring via multimeters	Measuring via AR
Visualizations via infographics	IG & MM	
Visualizations via simulation	SIM & MM	
Visualizations via AR	AR & MM	AR & AR

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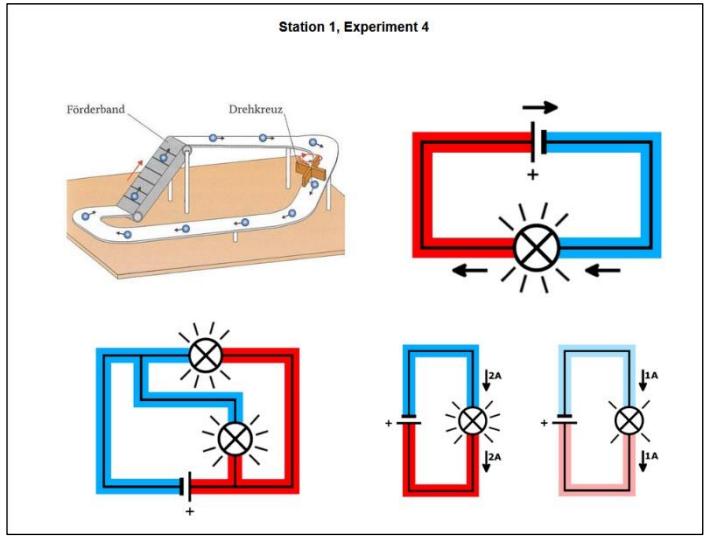
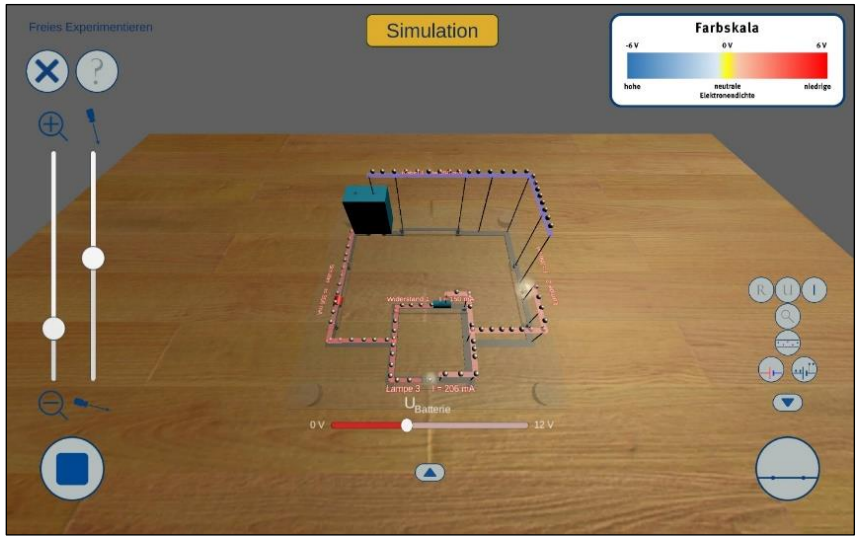
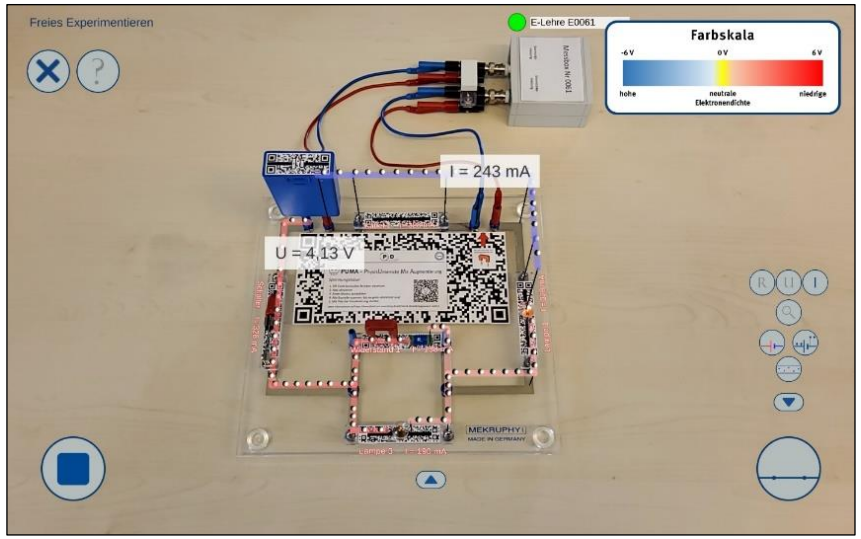
Differences between the groups



→ *Infographics*



→ *Simulation*



→ *AR-application*

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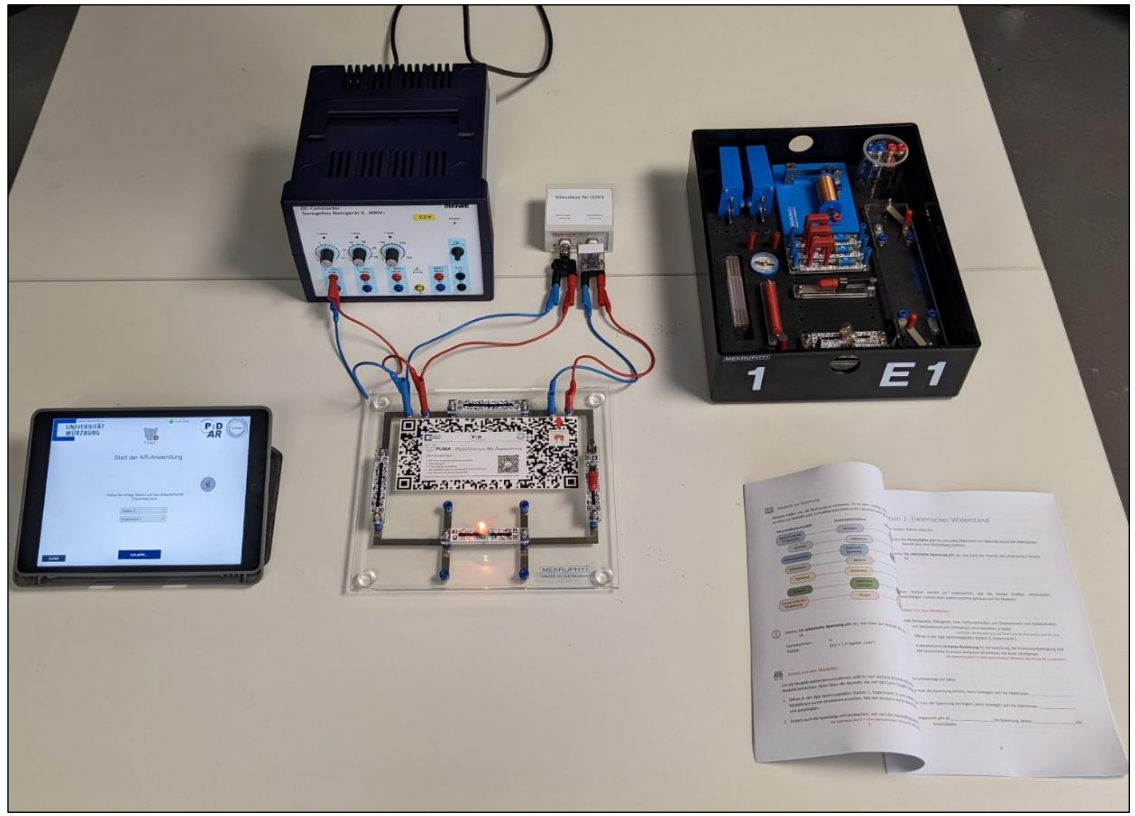
Context data on the intervention

Context of the intervention

→ Used in a student laboratory situated at University of Würzburg

→ Survey period: December 2022 – July 2023

→ Participants: 8 classes from secondary schools (in total 196 students), **after** completion of the introductory lessons on simple circuits



About the student laboratory

→ Four lessons: “Electric Current and Voltage”, “Electric Resistance”, “Parallel Circuits” and “Serial Circuits”

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Preliminary Results regarding Conceptual Knowledge

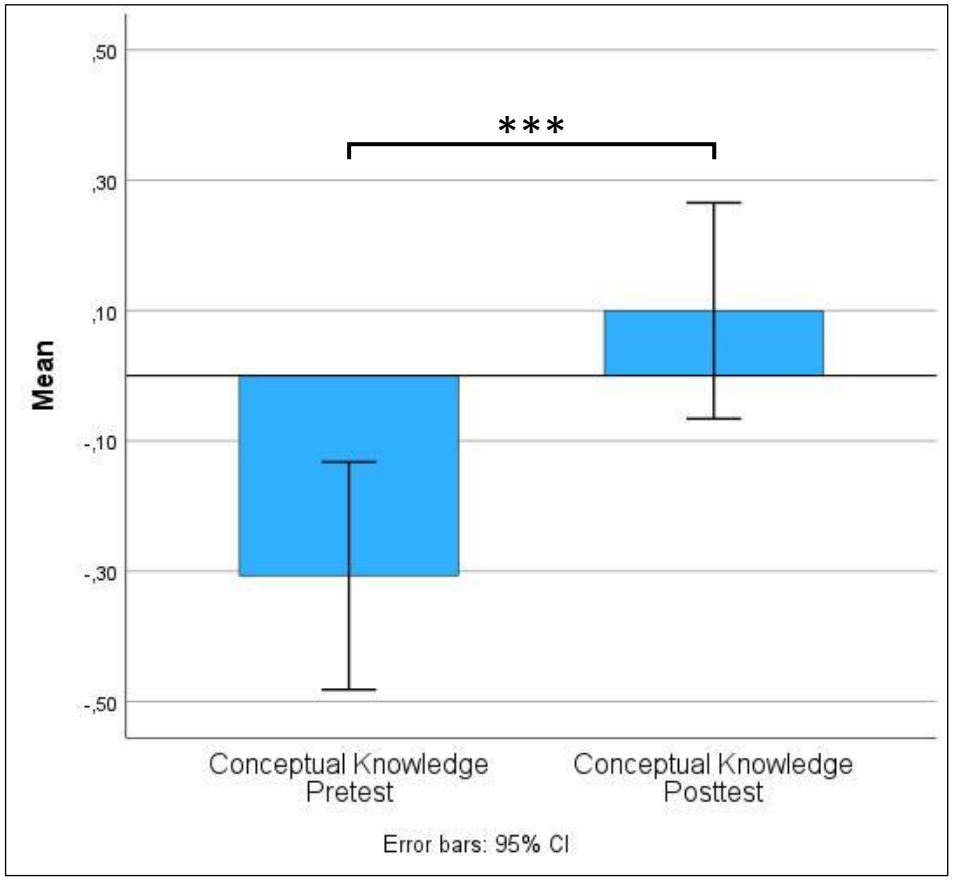
Preparing the Conceptual Knowledge Data

→ Test developed for IRT (Item Response Theory *(Bond et al., 2021)*) Analysis

→ Result: ability score for every participant for the Pre- and Post-Test (Range: -4.4 to 3.57)

Examining the full sample

→ A paired samples t-test showed a significant difference between Pre- (M = -.307, SD = 1.146) and Post-Test-Scores (M = .100, SD = 1.088); t(167) = -6.336, p < .001.



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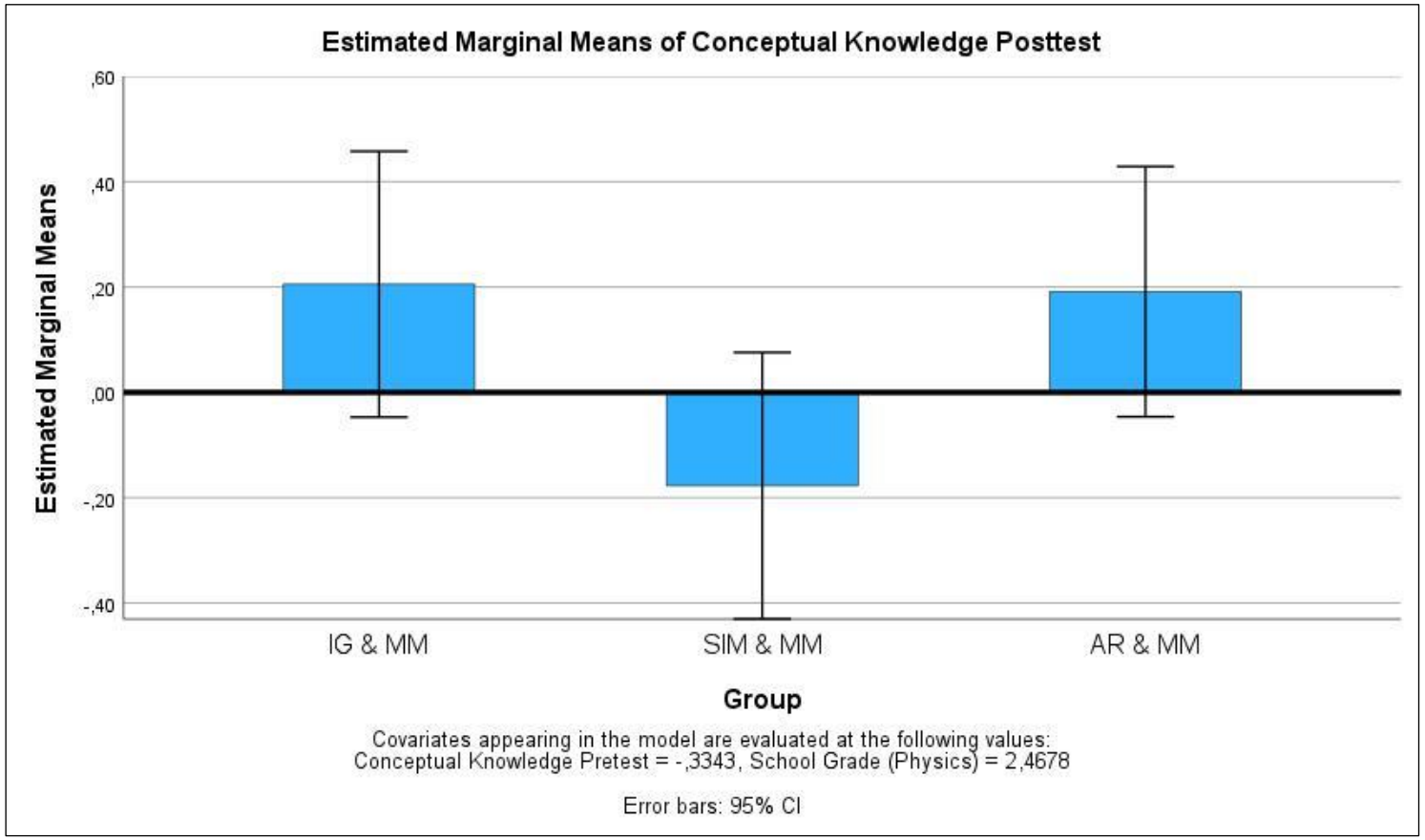
Preliminary Results regarding Differences caused by model presentation

Examining the model presentation

→ analysed using an ANCOVA (Post-Test-Score as dependant variable, group as fixed variable, with Pre-Test-Score and level of academic achievement as covariates)

→ With a p-value of .057, the ANCOVA revealed no significant effect of model presentation on Post-Test-Scores after controlling for the effect of the covariates, $F(2,108) = 2.939$, $p = .057$, partial $\eta^2 = .052$.



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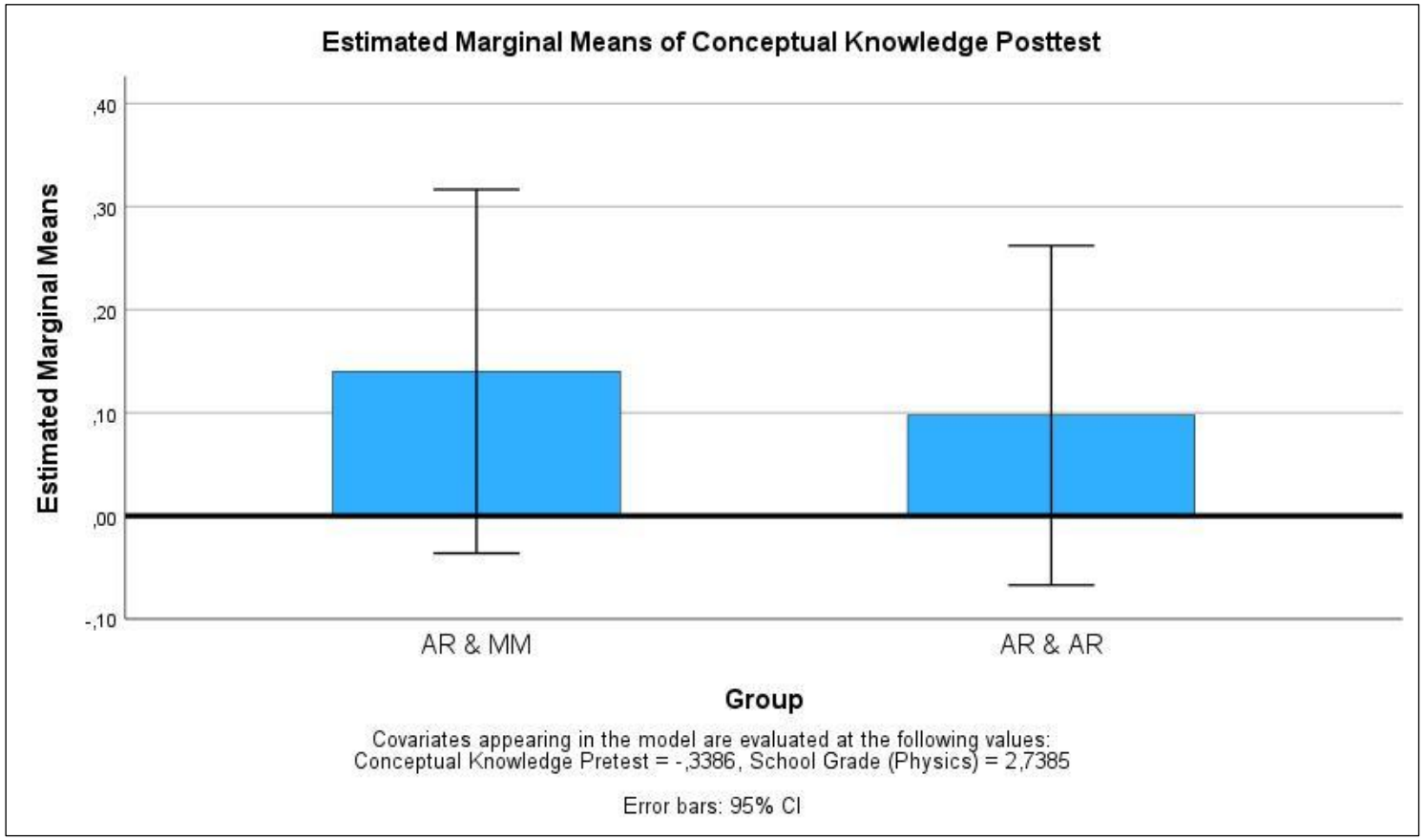
Preliminary Results regarding Differences caused by data acquisition

Examining the data acquisition

→ analysed using an ANCOVA (Post-Test-Score as dependant variable, group as fixed variable, with Pre-Test-Score and level of academic achievement as covariates)

→ With a p-value of .727, the ANCOVA revealed no significant effect of data acquisition on Post-Test-Scores after controlling for the effect of the covariates, $F(1,84) = 0.123$, $p = .727$, partial $\eta^2 = .001$.



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Preliminary Results regarding Time on Task and Post-Test-Scores

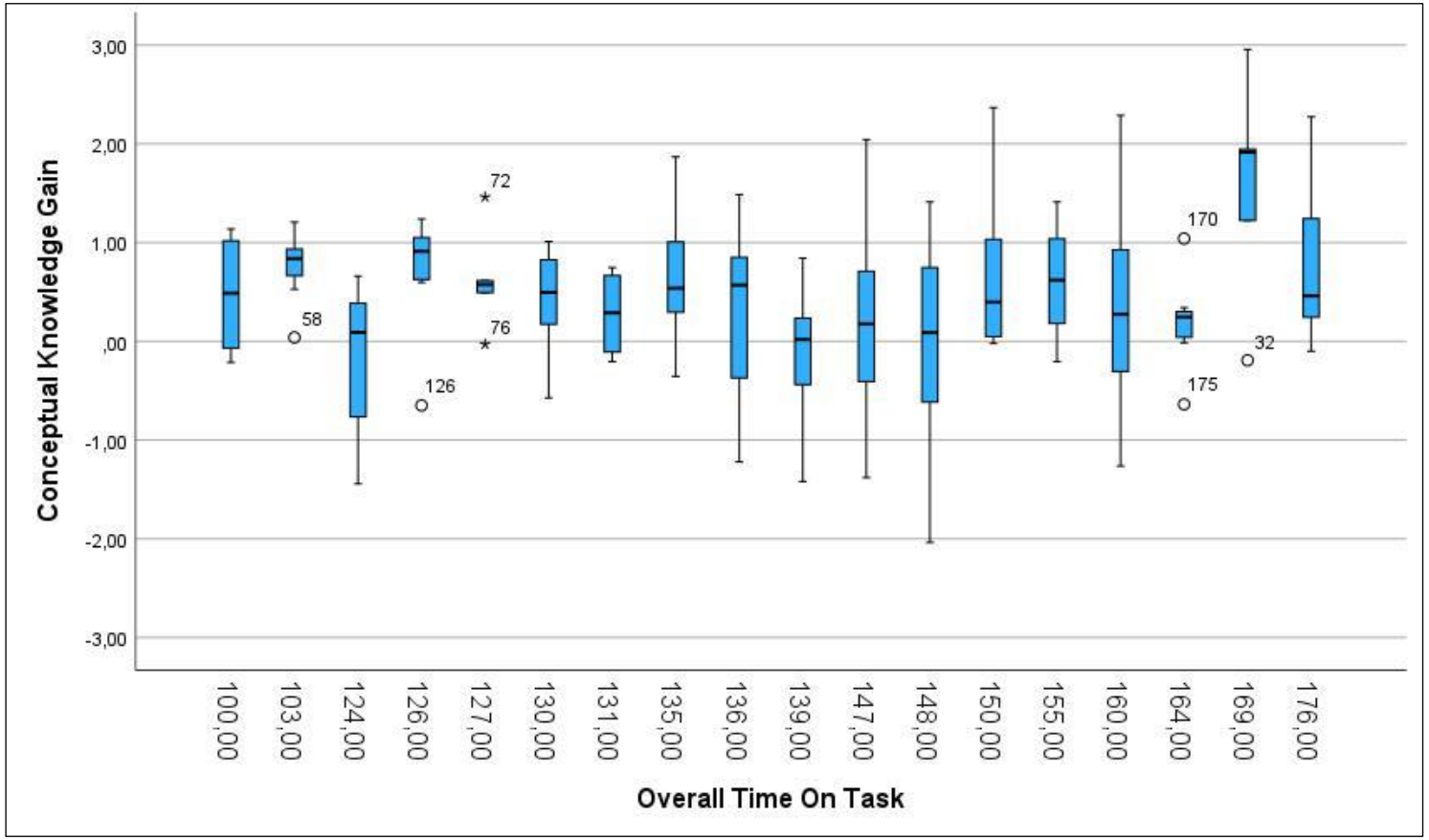
Examining the full sample

→ analysed using multiple linear regression

→ The regression was statistically significant ($R^2 = 0.55$, $F(3, 156) = 63.46$, $p < .001$).

→ Level of academic achievement ($\beta = -.176$, $p = .002$) and the Pre-Test-Score ($\beta = .668$, $p < .001$) significantly predict Post-Test-Score.

→ Time on Task does not significantly predict Post-Test-Score ($\beta = .043$, $p = .424$).



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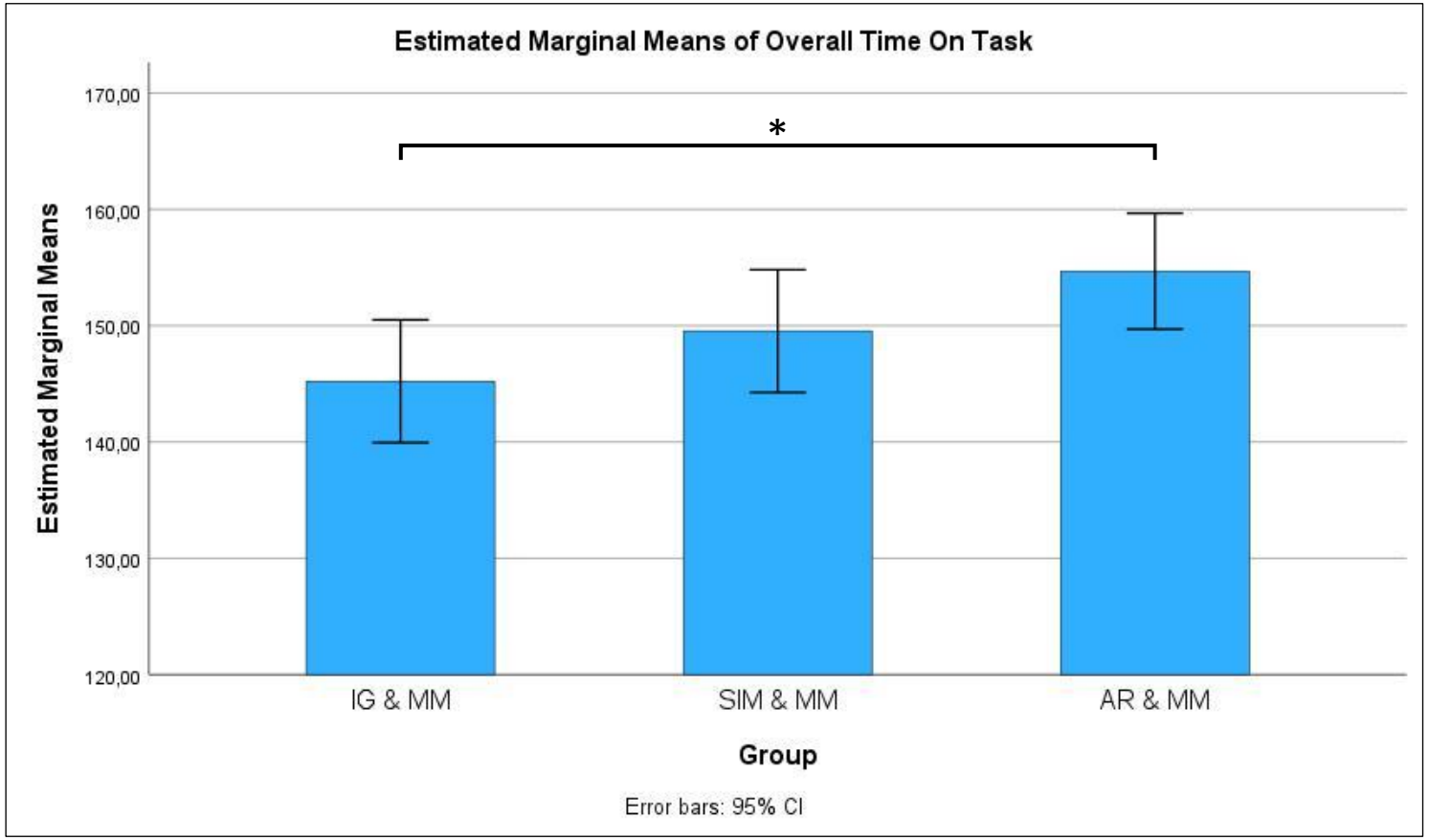
Preliminary Results regarding differences caused by model presentation

Examining the model presentation

→ analysed using an ANOVA

→ There was a significant effect of model presentation on Overall Time on Task, $F(2,125) = 3.344$, $p = .038$, partial $\eta^2 = .051$.

→ Post-Hoc-Tests revealed a significant increase in Mean Time on Task caused by using the AR-application as compared to using infographics, $p = .033$.



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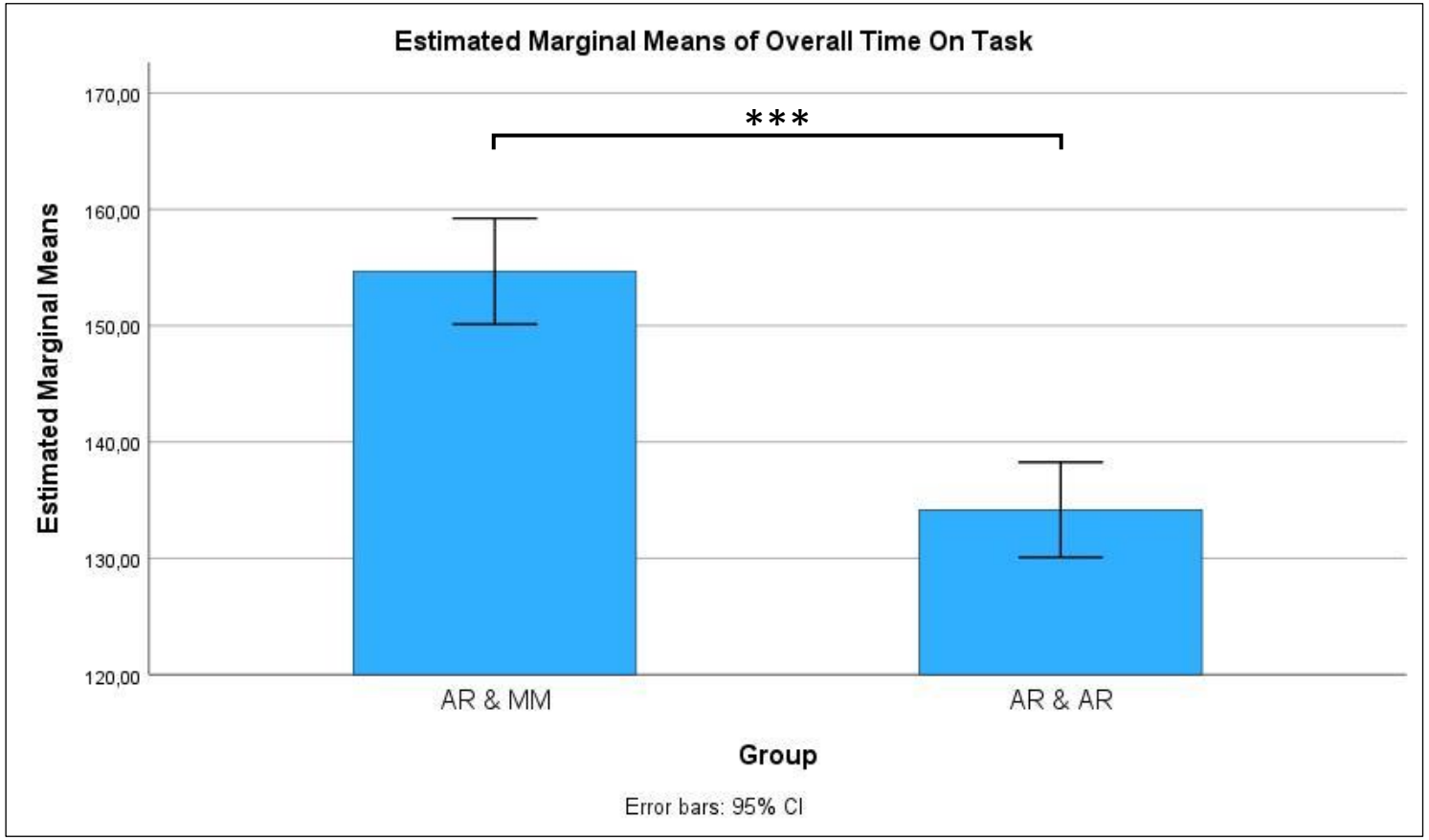
Preliminary Results regarding differences caused by data acquisition

Examining the data acquisition

→ analysed using an ANOVA

→ There was a significant effect of data acquisition on Overall Time on Task, $F(1,101) = 44.261$, $p < .001$, partial $\eta^2 = .305$.



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Summary

Summary of preliminary results

→ Significant Increase in Conceptual Knowledge caused by the intervention

→ No interaction between Conceptual Knowledge Development and Time on Task

→ Significant Increase in Time on Task when using AR for model presentation

→ Significant Decrease in Time on Task when using AR for data acquisition

Thank you for your attention!

More Information about the student lab and the app at:

https://go.uniwue.de/puma-s

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Literature cited in the presentation

Literature:

(1) Burde, Jan-Philipp (2018): Konzeption und Evaluation eines Unterrichtskonzepts zu einfachen Stromkreisen auf Basis des Elektronengasmodells. In: Studien zum Physik- und Chemielernen. Logos-Verlag, Berlin.

(2) Ivanjek, Lana; Morris, Louisa; Schubatzky, Thomas; Hopf, Martin; Burde, Jan-Philipp; Haagen-Schützenhofer, Claudia; Dopatka, Liza; Spatz, Verena; Wilhelm, Thomas (2021): Development of a two-tier instrument on simple electric circuits. In: Phys. Rev. Phys. Educ. Res. 17, 020123.

(3) Müller, Svetlana; Burde, Jan-Philipp; Wilhelm, Thomas (2015): Vergleich von Schülervorstellungen zur Elektrizitätslehre in Hessen und Weißrussland. In: PhyDidB, Didaktik der Physik, Beiträge zur DPG-Frühjahrstagung, 1 (2015).

(4) Fromme, Bärbel (2018): Fehlvorstellungen von Studienanfängern – Was bleibt vom Physikunterricht der Sekundarstufe I? In: PhyDid B, Didaktik der Physik, Beiträge zur DPG-Frühjahrstagung, 1 (2018), S. 205-215.

(5) Burde, Jan-Philipp; Wilhelm, Thomas (2020): Teaching electric circuits with a focus on potential differences. In: Phys. Rev. Phys. Educ. Res. 16, 020153.

(6) Mayer, Richard (2014): Cognitive Theory of Multimedia Learning. In (Mayer, Richard (Hrsg.)): The Cambridge Handbook of Multimedia Learning, Second Edition, S. 43-71. Cambridge University Press, New York.

(7) Mayer, Richard; Fiorella, Logan (2014): Principles for Reducing Extraneous Processing in Multimedia Learning: Coherence, Signaling, Redundancy, Spatial Contiguity, and Temporal Contiguity Principles. In (Mayer, Richard (Hrsg.)): The Cambridge Handbook of Multimedia Learning, Second Edition, S. 279-315. Cambridge University Press, New York.

(8) Mayer, Richard; Moreno, Roxana (2010): Techniques That Reduce Extraneous Cognitive Load and Manage Intrinsic Cognitive Load during Multimedia Learning. In (Plass, Jan; Moreno, Roxana; Brünken, Roland (Hrsg.)): Cognitive Load Theory, S. 131-152. Cambridge University Press, New York.

(9) Kapp, Sebastian; Lauer, Frederik; Beil, Fabian; Rheinländer, Carl; Wehn, Nobert; Kuhn, Jochen (2021): Smart Sensors for Augmented Electrical Experiments. In: Sensors, 22(1), 256.

(10) Klepsch, Melina; Schmitz, Florian; Seufert, Tina (2017): Development and Validation of Two Instruments Measuring Intrinsic, Extraneous, and Germane Cognitive Load. In: Front. Psychol. 8:1997.

(11) Karrer, Katja; Glaser, Charlotte; Clemens, Caroline; Bruder, Carmen (2009): Technikaffinität erfassen – der Fragebogen TA-EG. In (Lichtenstein, Antje; Stößel, Christian; Clemens, Caroline (Hrsg.)): Der Mensch im Mittelpunkt technischer Systeme. 8. Berliner Werkstatt Mensch-Maschine-Systeme (ZMMS Spektrum, Reihe 22, Nr. 29, S. 196 – 201). VDI Verlag GmbH, Düsseldorf.

(12) Heller, Kurt; Perleth, Christoph (2000): Kognitiver Fähigkeitstest für 4.-12. Klassen, Revision (KFT 4-12+ R). Hogrefe, Göttingen.

(13) Bond, Trevor; Yan, Zi; Heene, Moritz (2021): Applying the Rasch Model – Fundamental Measurement in the Human Sciences, Fourth Edition. Routledge, New York.