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Stargazing Live! Inspiring with semi-live astronomy data; teaching curriculum topics using smart education tools

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Abstract

Stargazing Live! aims to capture the imagination of learners with a combination of live and interactive planetarium lessons, real astronomical data, and lessons built around interactive knowledge representations. The lessons were created using a co-creation model and tackle concepts in the pre-university (astro)physics which students find difficult to grasp with traditional interventions. An evaluation study in 9 Dutch classrooms showed that learners are inspired and engaged by the planetarium lessons but are not always able to link the content to the classroom. Pre- and post-tests showed that the accompanying star properties activity significantly increased learners' understanding of the causal relationships between mass and other properties (such as luminosity, gravity, and temperature) in a main sequence star.

Keywords: Planetarium, Pre-university physics education, Conceptual modelling, Data in the classroom, Co-creation of resources

1 Introduction

Star formation, stellar properties and the associated physical laws are key topics in pre-university physics curricula. These concepts are often abstract and can be challenging for learners to grasp. Studies have found that learners often do not know that stars generate energy through nuclear fusion (Agan, 2004; Bailey et al., 2012), are unable to explain how stars form and do not realise that stellar mass is the main driver for the variation in stellar properties (Bailey et al., 2009). Research shows that traditional learning methods are not always effective, highlighting a need for new types of interventions which stimulate learners' conceptual understanding of astrophysical topics (Bailey et al., 2009).

The Stargazing Live! (Holt et al., 2021, 2022) project aims to capture the imagination of learners and stimulate deep learning of key curriculum topics by combining a planetarium experience with conceptual modelling activities. Planetariums play a key role in the learning of astronomical concepts by sparking interest (Schmoll, 2013; Plummer and Small, 2013), providing a unique and immersive (3D) learning environment (Plummer et al., 2014), which improve retention (Greca and Moreira, 2002), particularly when the experience is live and interactive allowing learners to participate and ask questions (Schmoll, 2013; Schultz and Slater, 2021; Plummer and Small, 2013). Combining a planetarium experience with traditional activities can provide a well-rounded learning experience (Plummer et al., 2014; Plummer and Small, 2018).

Furthermore, the Stargazing Live! project inspired by integrating real data into the interactive planetarium experience. The follow-up computer-based lessons trigger deep learning by challenging learners to build and simulate cause-effect models, which help to build and refine the learner's own conceptual understanding (Doyle and Ford, 1998; Greca and Moreira, 2002). In this article we describe the co-creation development process (section 2), the lessons (sections 3 & 4) and summarise the results of the evaluation study (section 5).

2 Co-creation 3.0

Whilst it is now recognised that education experts should be included in the creation of lesson materials, the level of involvement is variable. This project is different in that it combines the expertise of i) astronomers and astronomy education/public engagement professionals, ii) science education experts and iii) secondary school physics teachers. Expertise from all groups has been drawn upon in all stages of the project, starting with a wide-scale teacher survey and focus group discussions. Although we refer the readers to (Holt et al., 2021) for more details, here we would like to highlight one key finding which had a major impact on subsequent work in the project. Whilst highly engaged physics teachers are keen to see new results and insights from the scientific world, the majority of survey respondents suggested that a strong link to the curriculum is key and the main driver for teachers in deciding which activities to give to their students (Holt et al., 2021). These results drastically changed the further development of the planetarium lesson and accompanying lesson activities.

3 Planetarium lesson including semi-live data

The planetarium lesson focusses on the transient universe and covers a range of variable phenomena in the universe including (near Earth) asteroids, variable stars, (super)novae and gravitational wave events such as kilonovae. These topics link to both the main science goals of the BlackGEM (`https://www.blackgem.nl`) and MeerLICHT (`https://www.meerlicht.nl`) telescopes and the Dutch pre-university school physics curriculum.

The lesson is modular allowing the specific focus to be easily changed depending on the group and the wishes of the school. As with all NOVA Mobile Planetarium lessons, the lesson is live and interactive (Holt et al., 2023).

A unique feature is the inclusion of semi-live telescope data from MeerLICHT and BlackGEM. Image sets are used to introduce each topic and instigate a discussion – what could the changing features in the images be? Once ideas are exchanged, the lesson continues to explain what is being shown in each dataset. Key curriculum topics are included such as Wien's Law and the Stefan-Boltzmann Law. Image artefacts are also a key element in the discussion.

4 Conceptual modelling in DynaLearn

The conceptual modelling activities are designed to extend the planetarium lesson, trigger deep learning, and improve conceptual understanding of key topics in the Dutch pre-university physics curriculum. Specific topics highlighted in the teacher survey included a conceptual understanding of star formation and star properties and the associated physical laws (e.g., Wien's law and the Stefan-Boltzmann law). The lessons were created using the DynaLearn software (`https://www.dynalearn.eu`) (Bredeweg et al., 2023a).

The lessons challenge learners with concept modelling, which is subtly different to the more common concept mapping. Whilst both techniques break a concept into sub-concepts and the relationships between them, in conceptual modelling the relationships are *causal* relationships allowing learners to actually *simulate* the model they create in the software.

DynaLearn provides a qualitative vocabulary to represent conceptual models (Forbus, 2018). The models are not numerical but use logic-based algorithms to simulate outcomes (Bredeweg et al., 2009). DynaLearn allows for models to be created with different degrees of complexity; the higher the level, the richer the vocabulary to express the model (Bredeweg et al., 2023a). The software uses various scaffolds to support the learner.

Three lesson activities have been developed at different complexity levels in DynaLearn: Star Properties (level 2), Star States (level 3) and Balance within a Star (level 4). In this short article we focus on the Star Properties lesson and refer the reader to (Bredeweg et al., 2023c) for details of the other lessons.

Learners work independently through a workbook which guides them step by step through the creation of the model (Figure 1). Learners receive automated support and feedback through help functions within the application. See (Bredeweg et al., 2023a,c,b, 2009)for more details.

5 Evaluation study

The lessons were evaluated in a three-tier process. First, the star properties lesson was tested by 3 astrophysics master students. Second, physics teachers reviewed the lesson during a 90-minute teacher-training session. Finally, the full intervention (planetarium & star properties activity) was tested in Dutch classrooms (n=152, grade 11-12, 9 classes, 3 secondary schools). Learners began with 50 minutes in the planetarium, then continued with the 90-minute computer activity. Learners had no

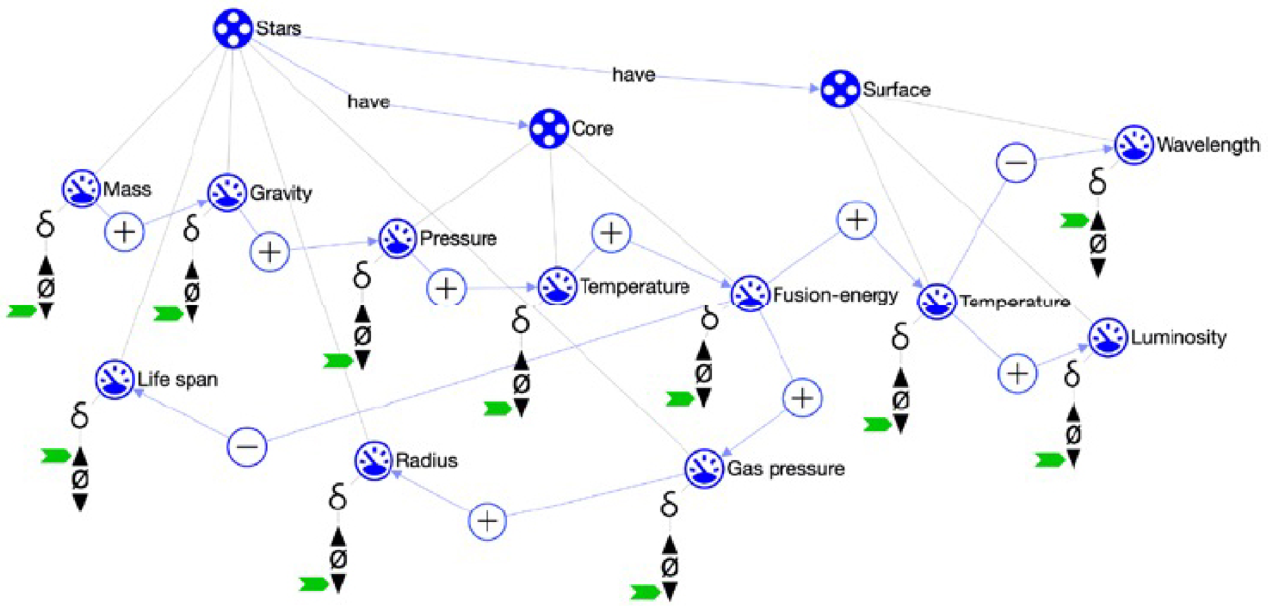

Figure 1. Star Properties model & simulation. The model comprises three entities (Stars, Core, Surface), two configurations (2x have), eleven quantities (Mass, Gravity, Pressure, Temperature (of the core), Fusion-Energy, Temperature (of the surface), Luminosity, Gas Pressure, Radius & Life Span) and ten causal dependencies (2 negative and 8 positive). Each quantity can have three values (∂): increasing (▲), constant (∂) and decreasing (▼). This image displays the model in the simulation mode. The user has set the initial Mass to be decreasing. How the other quantities will change depends on their proportional relationship with the preceding quantity, indicated by the green arrows.

prior experience of the planetarium, the software or learning by constructing qualitative representations.

The planetarium lesson was evaluated using a short questionnaire completed immediately after the planetarium lesson including 7-point Likert-scale statements and open-ended questions. Learners were asked about the experience, the inclusion of real data and the link between the planetarium lesson and curriculum topics. The planetarium lesson scored highly on most aspects although learners did not readily recognise that key curriculum topics were being taught in the planetarium (see (Bredeweg et al., 2023b,c)).

The star properties lesson was evaluated using identical pre- and post-tests. Items related to the astrophysical content of the lesson and qualitative reasoning vocabulary. Results showed a significant positive effect of conceptual modelling on learners' understanding of both the causal relationships between quantities of stars in the main sequence and in the use of qualitative vocabulary. Paired t-tests showed that there is a significant difference between the score on all pre-test and post-test items ($p < 0.5$). The highest score increases were for the items relating to the qualitative vocabulary 'What is an entity' and 'Simulation results' (.41 and .38 points respectively) and for the items relating to the effect of mass on stellar life span (Ls, .55 point increase) and on the peak observed wavelength (W, .36 point increase). We refer readers to Bredeweg et al. (2023b; 2023c) for more a more detailed discussion of the evaluation results.

6 Conclusions

The Stargazing Live! project combines a live and interactive planetarium experience using real data and complimentary computer-based conceptual modelling lessons to teach key curriculum topics in the pre-university physics curriculum. The evaluation study showed that learners found the lessons to be inspiring and enjoyable. Furthermore, the intervention significantly improved learners' conceptual understanding of the causal relationships between quantities of stars in the main sequence and their use of qualitative vocabulary. All lessons are available in English and Dutch via the authors.

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References

Agan, L. (2004). Stellar ideas: Exploring students' understanding of stars. *Astro. Edu. Review*, 3(1):77–97. (https://www.doi.org/10.3847/AER2004013.

Bailey, J. M., Johnson, B., Prather, E. E., and Slater, T. F. (2012). Development and validation of the star properties concept inventory. *Int. J. of Sci. Edu.*, 34(14):2257. (https://www.doi.org/10.1080/09500693.2012.671714.

Bailey, J. M., Prather, E. E., Johnson, B., and Slater, T. F. (2009). College students' pre-instructional ideas about stars and star formation. *Astro. Edu. Review*, 8(1):010110. (https://www.doi.org/10.3847/AER2009002.

Bredeweg, B., Kragten, M., Holt, J., Kruit, P., van Eijck, J., Pijls, M., Bouwer, A., Sprinkhuizen, M., Jaspar, E., and de Boer, M. (2023a). Learning with interactive knowledge representations. *Applied Sciences*, 13(9):[5256]. (https://www.doi.org/10.3390/app13095256.

Bredeweg, B., Kragten, M., Holt, J., Vaendel, D., Hanse, J., and Bloemen, S. (2023b). Qualitative models to learn about star properties, star states and the balance between fusion and gravity. In *36th International Workshop on Qualitative Reasoning*, Krakau, Poland.

Bredeweg, B., Kragten, M., Holt, J., Vaendel, D., Hanse, J., and Bloemen, S. (2023c). Stargazing live! inspiring with real data in a mobile planetarium and learning through conceptual modelling. In *Augmented Intelligence and Intelligent Tutoring Systems*.

Bredeweg, B., Linnebank, F., Bouwer, A., and Liem, J. (2009). Garp3 – workbench for qualitative modelling and simulation. *Ecological Informatics*, 4(5-6):263–281. https://www.doi.org/10.1016/j.ecoinf.2009.08.004.

Doyle, J. K. and Ford, D. N. (1998). Mental models concepts for system dynamics research. *System Dynamics Review*, 14(1):3–29. https://www.doi.org/10.1002/(SICI)1099-1727(199821)14:1<3::AID-SDR158>3.0.CO;2-P.

Forbus, K. D. (2018). *Qualitative Representations: How People Reason and Learn About the Continuous World*. The MIT Press, Cambridge, MA.

Greca, I. M. and Moreira, M. A. (2002). Mental, physical, and mathematical models in the teaching and learning of physics. *Science Edu.*, 86(1):106–121. https://www.doi.org/10.1002/sce.10022.

Holt, J., Hanse, J., and Baan, M. (2023). The nova mobiel planetarium: 10 best practices for planetarium projects based on an astronomy education success story. *Comm. Astronomy with the Public Journal – Special Issue on Planetariums*. https://www.doi.org/10.3389/faspa.2023.871175.

Holt, J., Hanse, J., Baan, M., Groot, P., and Bloemen, S. (2021). Co-creation 3.0: Taking the development of astronomy education resources to the next level in the project star-gazing live! In *Proc. of the 3rd Shaw IAU Workshop on Astronomy for Edu.* IAU.

Holt, J., Hanse, J., Vaendel, D., Kragten, M., Bredeweg, B., Bloemen, S., Baan, H. M., and Groot, P. (2022). Stargazing live! inspiring with semi-live astronomy data; teaching curriculum topics using smart education tools. In *Proc. of the 4th Shaw IAU Workshop on Astronomy for Edu.* IAU.

Plummer, J. D., Kocareli, A., and Slagle, C. (2014). Learning to explain astronomy across moving frames of reference: Exploring the role of classroom and planetarium-based instructional contexts. *Int. J. of Science Edu.*, 36(7):1083–1106. https://www.doi.org/10.1080/09500693.2013.807296.

Plummer, J. D. and Small, K. J. (2013). Informal science educators' pedagogical choices and goals for learners: The case of planetarium professionals. *Astro. Edu. Rev.*, 12(1):1. https://www.doi.org/10.3847/AER2012001.

Plummer, J. D. and Small, K. J. (2018). Using a planetarium fieldtrip to engage young children in three-dimensional learning through representations, patterns, and lunar phenomena. *Int. J. of Science Edu.*, 8(3):193–212. https://www.doi.org/10.1080/21548455.2017.1386656.

Schmoll, S. E. (2013). *Toward a Framework for Integrating Planetarium and Classroom Learning*. Doctoral dissertation.

Schultz, K. K. and Slater, T. F. (2021). Use of formative assessment-based active learning by astronomy educators teaching in live planetarium learning environments. *Joural of Astronomy & Earth Sciences Education*, 8(1):27–38. https://www.doi.org/10.3847/2041-8213/ab5bfb.