

STARGAZING LIVE! Inspiring students with semi-live astronomy data in the planetarium; teaching curriculum topics using smart education tools

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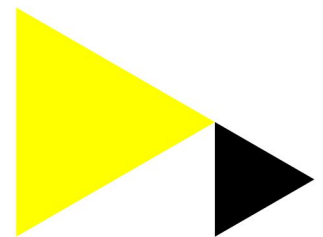
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The International Planetarium Society

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A Message from the Conference Hosts

Dear Friends and Colleagues,

It is with great pride and excitement that we present to you the official proceedings of the 2024 International Planetarium Society Conference, held in Jena and Berlin, Germany. This landmark event brought together 693 participants from 55 different countries, creating an inspiring platform for exchange, innovation, and collaboration within the planetarium community.

The 2024 conference was an enjoyable culmination of four years of hard work and meticulous planning. It was a true pleasure to witness the camaraderie, collaboration, and dedication that our global community brings to the field. The discussions and presentations reflected not only the cutting-edge developments in our profession but also the strong bonds that connect us across borders.

This volume contains the documentation of delegate presentations, capturing the innovative ideas, research, and expertise shared during the event. We hope it will serve as a valuable resource and a reminder of the spirit of cooperation that defines our field.

We look forward to being united under the sky with you again at the IPS 2026, in Fukuoka, Japan. Until then, let us continue to inspire together.

Viele Grüße



Stefan Harnisch
Director
Zeiss-Planetarium Jena



Tim F. Horn
President
Stiftung Planetarium Berlin



A Message from the IPS President

Dear Friends and Colleagues,

It is my great honor to welcome you to the Proceedings of the 2024 IPS Conference. After years of preparation and anticipation, this extraordinary gathering in Jena and Berlin has proven once again why the planetarium community is one of the most vibrant, creative, and collaborative groups in the world. For those who were able to attend the conference, I hope these Proceedings serve as a time capsule of sorts – a way to revisit the ideas, innovations, and connections that made the experience so memorable. For those who couldn't join us in person, this document offers a glimpse into the wealth of knowledge and inspiration shared among colleagues from across the globe.



This conference marked a return to shared spaces, shared stories, and shared visions for our future. The world has felt both vast and small in recent years, as we've navigated challenges together and apart. Yet here we were – gathered under the same skies, in the same domes – reigniting the spark that has always driven our work forward.

These Proceedings, much like the conference itself, are a testament to the talent, dedication, and sheer brilliance of our community. From groundbreaking research to hands-on workshops, the contributions of our members continue to push the boundaries of what planetariums can achieve. I am endlessly inspired by the way we strive not just to innovate, but to elevate one another in the process.

As always, none of this would have been possible without the incredible efforts of our hosts, the teams at Zeiss-Planetarium Jena and Stiftung Planetarium Berlin. To the organizers, speakers, sponsors, and attendees – thank you for making this conference a shining example of what collaboration can accomplish.

Looking through these pages, I am reminded of the core truth of our field: that the work we do has the power to connect, inspire, and transform. Whether it's through the stories we tell under the dome, the technologies we develop, or the partnerships we forge, planetariums are uniquely positioned to spark wonder and understanding in audiences of all kinds.

As we turn the page on this conference and look toward the future, I encourage you to keep sharing your ideas, your challenges, and your aspirations. It is through this exchange that we continue to grow – as individuals, as organizations, and as a global community united by a love for the stars.

With gratitude and hope,
Michael McConville
IPS President, 2022–2024

Note from the Editor

These proceedings contain texts for many of the papers and presentations given at the IPS 2024 conference hosted jointly in Jena and Berlin, Germany.

Thank you to all the authors for your invaluable contributions to the field of planetarium education and outreach, as well as both Zeiss-Planetarium Jena and Stiftung Planetarium Berlin for their cooperation.

The included texts have been minimally formatted to ensure a consistent and uniform appearance across the compilation, though every effort has been made to preserve the integrity of each submission. All content is presented as expressed in the author's own words, without alteration to their intended meaning, tone, or style.

We are grateful to all the sponsors, organizers, and attendees for making our conferences possible. Without you and your support, gatherings on this scale would not be possible.

Special thanks to Anna Green, Michael McConville, and Mike Smail for their guidance and assistance in compiling my first IPS Proceedings document.

I would also like to take a moment to honor the late Dale Smith, former IPS Publications Chair, whose years of dedication to this role and to the IPS community set a standard of excellence. His previous proceedings documents served as invaluable references in the creation of this compilation. Though I never had the privilege of knowing Dale personally, his contributions to the planetarium field and his passion for education continue to inspire.

A handwritten signature in black ink, appearing to read 'Scott Mitchell', with a stylized 'S' and 'M'.

Scott Mitchell
Proceedings Editor & IPS Publications co-chair
Director, MARS Portable Planetarium
November 2024

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

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Abstract

Stargazing Live! aims to capture the imagination of students of all ages with live and interactive (mobile) planetarium lessons about the transient universe incorporating semi-live data from the Dutch MeerLICHT and BlackGEM telescopes. The most advanced lesson, at pre-university physics level, also aims to support the teaching and learning of key curriculum concepts. Results from the evaluation study show that pre-university physics students are engaged and inspired by the planetarium lesson but find it difficult to link the topics to what they learn in their physics lessons, supporting the need for follow-up classroom-based activities. To address this omission, lesson activities have been created for this age group to accompany the planetarium shows using the interactive tool DynaLearn (<https://dynalearn.nl/>). The lessons challenge students to model key curriculum concepts linked to the telescopes and their science such as stellar properties and the balance within a main-sequence star. The lessons were created using a co-creation model – led by science education experts with significant input from astronomers, astronomy outreach/education professionals and physics teachers. Knowledge questionnaires, completed immediately prior to and after the ‘stellar properties’ activity showed a significant increase in the number of students able to correctly describe the causal relationships between mass and other properties in a main-sequence star such as luminosity, gravity, and temperature. All materials are freely available in both English and Dutch (<https://www.astronomie.nl/stargazinglive>).

1. Introduction

Stellar properties, star formation and the physical laws associated with these topics are key concepts in pre-university physics courses curricula. However, these topics are challenging and abstract and learners often struggle to grasp them. Research has shown that learners often do not know that stars are powered by nuclear fusion (e.g. Agan, 2004; Bailey et al., 2012), that mass is the main driver of variation in stellar properties (e.g. Bailey et al., 2009) and can not explain how stars are formed. Traditional methods are not always effective for the teaching and learning of these

types of concepts; new approaches are required to support and stimulate learners' conceptual understanding of astronomy topics (Bailey et al., 2009).

Stargazing Live! (Holt et al., 2021, 2022, 2024) is an innovative project which aims to both capture the imagination of learners through a live and interactive planetarium experience and to stimulate deep learning of core curriculum topics through conceptual modelling tasks. Planetariums have long played a role in the teaching and learning of astronomy concepts. Planetariums provide an inspiring (Schmoll, 2013; Plummer & Small, 2013), unique and immersive 3-D learning environments (Plummer, Kocareli & Slagle, 2014) which can improve learner retention (Greca & Moreira, 2002), particularly when learners have the opportunity to participate and ask questions as is the case in live and interactive experiences (Schmoll, 2013; Schultz & Slater, 2021; Plummer & Small, 2013). Extending and complimenting a planetarium visit with classroom activities can provide a well-rounded learning experience (Plummer et al., 2014; Plummer & Small, 2018).

The Stargazing Live! Project combines a new planetarium experience with computer-based lessons (Holt et al., 2021, 2022, 2024; Bredeweg et al., 2023a,b). The planetarium lessons are live and interactive (Holt et al., 2023) and make use of real data in the dome. The follow-up computer lessons challenge learners to build and simulate cause-effect models of the topics introduced in the planetarium, triggering deep learning in which learners build and refine their own conceptual understanding (Doyle & Ford, 1998; Greca & Moreira, 2002).

In this article, we describe the project including the co-creation development process (section 2), the planetarium and computer lessons (sections 3 & 4) and summarise the results of the evaluation study (section 6).

2. Co-Creation 3.0

A large number of astronomy education resources are created by astronomers with no formal educational experience. In recent years, it has been recognised that education experts should be included in the development of resources, an idea often referred to as 'co-creation'. However, the level of involvement is variable. The Stargazing Live! Project is very different. The development team combines the expertise of i) astronomers and astronomy education/public engagement professionals, ii) science education experts and iii) secondary school physics teachers. In addition, *all groups* have contributed during *all stages* of the project. See Holt et al. (2021) for more details.

During the design phase, secondary school physics teachers were consulted through a wide-scale teacher survey. Teachers were also invited to participate in follow-up focus group discussions. The results influenced the choice of concepts to include (planetarium and lessons) and the length and type of the extension classroom activities (Holt et al., 2021). One key finding which had a major impact on the shaping of the project was the discrepancy between 'highly engaged physics teachers'⁸ and the majority of physics teachers (Holt et al., 2021):

⁸ We define 'highly engaged physics teachers' as those who are particularly interested and engaged in astronomy topics, are often also amateur astronomers, and well known in the astronomy community through their attendance of many astronomy outreach and education activities.

- Highly engaged physics teachers are keen to see the latest results and learn about new insights and discoveries in the field. They typically have a preference for new project-work for their most advanced students.
- The majority of physics teachers preferred shorter activities with a clear link to curriculum topics, particularly those likely to feature in assessments.

These results had a major impact on the development of the planetarium lesson and the classroom activities.

Physics teachers were also involved in the evaluation of the lesson materials. The lessons were evaluated in the classroom (see below) and the teachers participating in this study were asked for feedback on the lessons prior to, during and after the evaluation lessons. See also section 5.

3. Planetarium lesson

The planetarium lesson focusses on *the transient universe*. Topics include (near Earth) asteroids, variable stars, (super)novae and gravitational wave events such as kilonovae. These topics are both key concepts in the Dutch pre-university school physics curriculum and are linked the main science goals of the MeerLICHT (www.meerlicht.nl) and BlackGEM (www.blackgem.nl) telescopes.

The planetarium lesson has a modular structure allowing the specific lesson to be tailored to the level of the group and the wishes of the school. Whilst there is a fixed story line, the lessons are still designed to be fully live and interactive, a key feature of the NOVA Mobile Planetarium vision (Holt et al., 2023). Each module is introduced with a dataset from MeerLICHT or BlackGEM (Holt et al., 2024). Pre-prepared data sets are integrated into the software for each topic but recent developments have also made it possible to include semi-live data. The aim of the data is to instigate a discussion in the planetarium – what could the changing features in the images be? Once ideas have been exchanged, the planetarium presenter continues with the module, explaining what is being shown in each dataset. Key curriculum topics include Wien's Law, the Stefan-Boltzmann Law and orbits. Image artefacts are also a key element in the discussion.

4. Conceptual modelling in DynaLearn

The computer-based conceptual modelling activities are designed to extend the planetarium lesson. The aim is to trigger deep learning and improve learners' conceptual understanding of key physics curriculum topics at pre-university level in the Netherlands. As discussed above, topics highlighted in the teacher survey and focus group discussions include a conceptual understanding of star formation and star properties and the associated physical laws such as Wien's Law and the Stefan-Boltzmann Law). The lessons were created using the DynaLearn software (www.dynalearn.eu) (Bredeweg et al., 2009, 2023).

The DynaLearn lessons challenge learners to model concepts. Whilst a concept model, at face value, looks like the more common concept mapping (e.g. Novak & Cañas, 2006), there are subtle differences. Both techniques visually represent a concept as a series of nodes (sub-concepts) interlinked by relationships. However, whereas concept maps are static, concept models link nodes with *causal relationships* allowing learners to *simulate* the model they create in the software.

Within DynaLearn, learners work with a qualitative vocabulary to create a conceptual model (Forbus, 2018). The models are not numerical but use logic-based algorithms to simulate outcomes (Bredeweg et al., 2009). It is possible to create models with different degrees of complexity within DynaLearn with higher-level, more complex models using a richer vocabulary to express the model (Bredeweg et al, 2023). Various scaffolds are also available to support the learner.

Three lessons at different complexity levels have been developed for the Stargazing Live! Project: *Star Properties* (level 2), *Star States* (level 3) and *Balance within a star* (level 4). In this article we focus on the Star Properties lesson. For further details including information on the other lessons, we refer readers to Bredeweg et al., (2023a,b,c). Figure 1 shows the final model for the Star Properties lesson in the software.

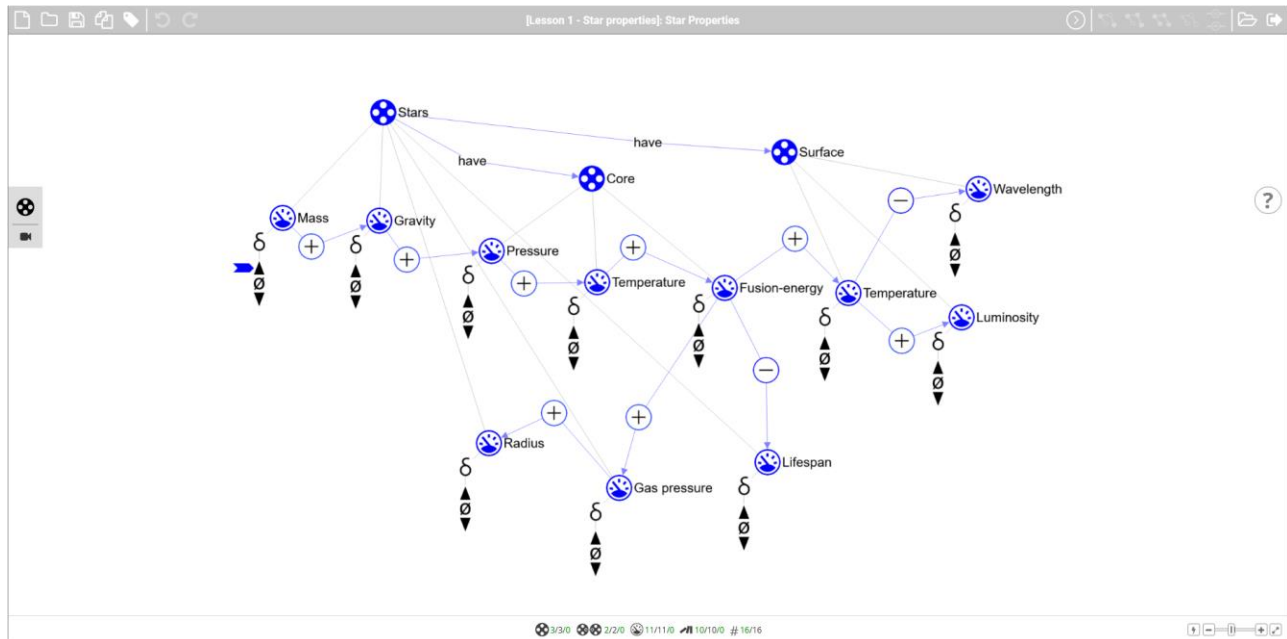


Figure 1: *Star Properties* model & simulation in the DynaLearn software. The model comprises three entities (*Stars*, *Core*, *Surface*), two configurations (2x *have*), eleven quantities (*Mass*, *Gravity*, *Pressure*, *Temperature* (of the core), *Fusion-Energy*, *Temperature* (of the surface), *Luminosity*, *Gas Pressure*, *Radius* & *Life Span*) and ten causal dependencies (2 negative and 8 positive). Each quantity can have three values (δ): increasing ($\blacktriangle$), constant ($\emptyset$) and decreasing ($\blacktriangledown$). 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.

During the lesson, learners work independently through a workbook. The workbook guides them through the creation of the model (Figure 1) step-by-step. Learners receive automated feedback through various help functions in the software. See Bredeweg et al. (2009, 2023a,b,c) for more details.

5. Evaluation study

The lessons were evaluated following a three-level procedure. 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. Third, the full intervention (planetarium & star properties activity) was tested in Dutch classrooms. In total, 152 grade 11-12 learners distributed over 9 classes in 3 secondary schools across the Netherlands took part in the evaluation study.

Learners first experienced the 50-minute lesson in the mobile planetarium. This was followed by the 90-minute conceptual modelling activity. Learners had no prior experience of the planetarium, the software or learning by constructing qualitative representations.

The planetarium lesson was evaluated using a short questionnaire containing both open-ended questions and 7-point Likert-scale statements. Learners completed the questionnaire immediately after the planetarium lesson. Learners were asked about their experience, the use of real astrophysical data in the planetarium and the link between the planetarium lesson and curriculum topics. Learners enjoyed the planetarium experience and scored almost all aspects highly. However, learners did not easily recognise that key curriculum topics were being taught in the planetarium. We refer readers to Bredeweg et al. (2003b,c) for more details.

The Star Properties lesson was evaluated using identical questionnaires. Learners completed the questionnaires immediately prior to the computer lesson (but after the planetarium lesson) and immediately after the lesson. The questionnaires comprised both open and multiple choice items relating to both the astrophysical content of the lesson and to 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. (2003b,c) for a more detailed discussion of the evaluation results.

6. Conclusions

Stargazing Live! is a project combining a live and interactive planetarium experience including real astrophysical data and complimentary computer-based conceptual modelling activities. The project aims to inspire and 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 full intervention (planetarium and computer lessons) 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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