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RESEARCH ARTICLE

A global demographic survey of planetarians

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Abstract

Planetariums have for a century played a vital role in bringing the wonders of the night sky (and the Universe) to people of all ages. One key part of the planetarium is the people who run the shows and interact with the public, who we call "planetarians". It is thus important to get an overview of who they are and how they operate.

In this work we report on a global demographic survey of planetarians. The aim is to provide a detailed overview of diverse profiles of the planetarians, the content they present, the ways in which they interact with the audience and how they grow in their profession. An extensive online, closed format, survey was constructed, checked for validity and distributed to planetarians worldwide, reaching 305 planetarians from 46 countries. The survey was translated into 11 languages to make it accessible to individuals who may not be confident in English. A mixed-methods approach to the analysis allowed for the exploration of the various layers and correlations between different constructs in the survey. Two overarching findings are: 1) planetarians seem to prioritise entertaining over educating; 2) planetarians seem to make no distinction between school audiences and the general public.

Keywords: Planetarium, Demographics, Survey

1 Introduction

Planetariums are places where one can be immersed in a visualisation of the night sky. There are roughly 4000 planetariums worldwide that receive an estimated 170 million visitors each year (Schultz and Slater, 2020; WPD, 2021). Planetariums are places that offer science communication (targeting the general public) and/or science education (often in the context of a school trip). In the context of teaching and learning, there is an increasing interest in researching what happens in the planetarium (Slater and Tatge, 2017).

Central to the learning, engagement and entertainment in a planetarium are the people that set educational goals, choose the content, develop the activities and visualisations, choose which films they present (or sometimes even develop 360° films), and offer activities that are complementary to what happens in the dome (e.g., exhibitions, youth workshops). We will refer to these people as the planetarians, which encompasses technicians who start full dome films, volunteers that explain the night sky, educators that present customised lessons to students and anything in between. We are aware that this is a wide group, yet all of them use the planetarium dome to educate, entertain or engage visitors in astronomy.

Given the central role of these planetarians, it is important to get an overview of them from various lenses. Schultz and Slater (2020) reported on a survey that attempted to answer the question "Who are the planetarians?". The work of Schultz and Slater provided initial insights from a limited geographical perspective.

Recognising the importance of the question posed by Schultz and Slater, in this current study we present the construction, distribution and response-analysis of a demographic survey that was distributed to planetarians worldwide.

Given that the planetarians operate in a professional context – the planetarium – we think it is important to include, in addition to personal characteristics, elements about their professional identity. As such, in addition to typical demographic questions, we asked questions regarding professional identity.

This paper starts by giving a brief overview of the relevant supporting literature leading to the different lines of inquiry explored in this study. Subsequently, we introduce the methodology underpinning this study. The results are presented and interpreted over several sections. Finally, we conclude with a discussion of the findings and directions for future work.

2 Literature

2.1 Planetarium Research

Planetariums have made an effort to become a global community with an international professionally-oriented magazine (Planetarian, nd), international conferences (e.g., International Planetarium Society conference, Symposium on Space Educational Activities, AstroEdu Conference, Shaw-IAU workshop, Communicating Astronomy with the Public Conference) and an effort to map out planetariums globally (WPD, 2021). The limited, mainly English-language research on planetarian demographics is predominantly focussed within the context of the United States of America, and other Anglo-Saxon countries. This current study undertook the ambitious goal to get an international perspective on the demographics of planetarians.

This study was motivated by the work of Schultz and Slater (2020), who referred to other planetarium-focused research that allowed them to establish some *a priori* hypotheses about planetarium operator demographics, but they indicated that there were no focused efforts prior to their work. Schultz and Slater found that planetarians are predominantly highly educated, that many do not have an astronomy or physics background, and a notably large portion has a background in theatre and performance-arts. Their findings suggest that "planetarium educators are a fundamentally different sort of individual than those who teach K-12 astronomy or do outreach as an amateur astronomer and, as such, perhaps have very different professional development requirements and expectations from those other astronomy education-related professional development consumers."(Schultz and Slater, 2020, p. 25). This diversity presents an opportunity to get a better picture of planetarians. Additionally, this raises the questions: Why planetarians choose to work in a planetarium? and who they are (professionally)?

The work of Schultz and Slater focussed on the North American context and was restricted in the sampling using a Facebook group call. This meant that the planetarians who participated in the survey were, in addition to being geographically concentrated, part of a specific Facebook group and thus self-selected because they responded to an open invitation. This raises the question as to the extent the reported findings of Schultz and Slater are internationally applicable.

More recently, the International Planetarium Society (IPS) released their 'Culture and Climate' report (Schmoll et al., 2021). This report focused on inclusivity, diversity, and equitability issues (e.g., gender, age, race, sexuality). While the focus of the report was different to the work presented in this study, the Culture and Climate report asked some demographic questions. They found that of planetarium staff (note that this includes planetarians but also people that take up management or executive roles, technical positions, and other) roughly 67% identified as male, 30% identified as female and 3% identified as non-binary or self-described (or preferred not to say). They also found that more than 80% have a higher education degree, which is in agreement with the study by Schultz and Slater (2020). Additionally, and in line with the way we will probe professional identity, the report asked questions about conference attendance, where a quarter of their respondents had never attended an IPS conference. It should be noted that the IPS survey reached predominantly planetarians in North America (USA and Canada) and Europe. This highlights the need for more international studies that provide a big picture view of various aspects of planetaria. This current study is one addition to this big picture view.

2.2 Informal Science Learning

A planetarium is one of many out-of-school science education institutions (others include zoos, aquariums, science centres, science museums, natural history museums, natural reserve parks, public observatories). While these institutions are similar in the sense that they provide science education and operate beyond school walls, there are large differences between them. A science museum will allow visitors to choose what they spend time on. In a science centre visitors can interact with exhibits and can choose how much time they spend on different exhibits. In comparison, in a planetarium, visitors have much less (almost no) control over their own learning paths while in the dome. This is more akin to some traditional formal educational settings. As such, regarding the educational activities, a planetarium may be labelled as a formal out-of-school science education institution. We will refer to formal learning in a school setting as compulsory education.

Despite this, planetariums are often considered to be informal learning spaces, in part because there is no generalisable consensus on how to exactly define formal, informal, non-formal learning environments (Plummer et al., 2015). It is thus informative to look at the literature focussing more broadly on informal learning. Beyond the science education context, demographic studies have been conducted of, for example, art museum educators (Zeller, 1985), which was recently revisited and expanded upon by Kletchka (2021). Kletchka went beyond a narrow demographic study, by using an online quantitative questionnaire, that explored the demographics, educational background, and professional experience. Kletchka found that art museum educators in the USA are quite homogeneous (white, female, cisgender, heterosexual, middle-class, married) and that many have less than 10 years of experience (meaning that there is a lot of staff turnover). Another recent work by Erickson (2021), using a multiple case study approach consisting of interviews, focused predominantly on the institutional level, reported on the role and nature of informal educators in science centers, science museums and zoos. Erickson found that the informal science education institutions he visited had "similar expectations of their educators and their responsibilities" (p.2). That is, the educators are responsible for "ensuring programs and experiences are engaging" (Erickson, 2021, p.21), for fostering critical and scientific thinking and for ensuring that every visitor, regardless of background or experience, learns something new. However, at an organisational level there are differences between the institutions. Some educators are responsible for all aspects, from creating educational materials to ordering supplies, others have a limited responsibility (e.g., focusing on family programs). As such, it was important to incorporate all people that are involved in operating the planetarium dome in our study.

2.3 Professional Identity

The professional identity of educators is extensively researched in the context of formal school education (Beijaard et al., 2004; Kelchtermans, 2009). This is, for example, evident from the many validated quantitative instruments that assess teachers' professional identity, which taken together focus on six elements of professional identity: self-image, motivation, commitment, self-efficacy, task perception, and job satisfaction (Hanna et al., 2019). However, much less is known about the professional identity of educators in out-of-school science education institutions.

Bailey (2006) reported on USA museum educators' perceptions of their roles, identity, and practice through in-depth interviews. Bailey finds that "for many of these individuals being an educator and a science educator is 'who they are'" (p. 194). In other words, their professional identity is closely related to their personal identity.

In addition to asking "Who am I at this moment?", Beijaard, Meijer and Verloop (2004, p.108) state that professional identity is not static and thus also asks "Who do I want to become?" (p.122). In other words, engagement with professional development (e.g., through reading research, following workshops, attending conferences etc.) is a part of professional identity. Here too research is predominantly focused on formal learning environments and research on professional development of planetarians is rare.

Plummer and Small (2013) found that while 83% (N=36) of planetarians engaged with professional development, this was not the primary way through which planetarians evaluate and design their teaching practices. Rather, planetarians rely on "personal experiences on the job and working with the audience" (p. 8). Yet, reflective practices, which are critical for the professional development of informal science educators, should also include evaluating teaching using research, and linking theory and practice (Patrick, 2017).

2.4 Interactions

In addition to demographics and professional identity, this current study also includes questions about the planetarians' professional practices. In particular, we are interested in the way planetarians interact with their school audiences, teachers, and general public. One type of interaction is feedback from the visitors towards the improvement of planetarium activities and programs. Another type of interaction is part of the science communication or science education program. In this case, planetarians engage with visitors, using the rich context of topics in astronomy and cosmology for question-and-answer sessions, discussions, and deep conceptual and spatial reasoning (e.g., Cole et al., 2018; Padalkar, 2010; Salimpour et al., 2021b).

Note that 'interaction' is broadly defined here. Interaction refers to the extent choices with regard to education or communication are motivated by the public. A low level of interaction might be a question-answer interaction where the answer is obvious (e.g., Which planet do we see now? while showing the Earth). A higher level of interaction might allow visitors to choose the next astronomical object that is 'visited'. Note that interaction can be direct (e.g., Are teachers contacted to decide the focus of the planetarium visit?) or indirect (i.e., a question of a visitor might change future presentations). Regardless of the type or level of interaction, planetariums should take advantage of the opportunities and learning benefits of student-centred pedagogies with the aim of motivating and engaging a new generation of thinkers.

There is a general consensus that interaction is important to stimulate student learning (Mercer, 2000; Taylor, 2015; Wegerif et al., 1999) [1]. In addition, in the context of planetarium lessons for school audiences in small planetariums, scholars have highlighted the importance of interactions ((Mallon and Bruce, 1982) as cited in (Slater and Tatge, 2017)). Although the research is sparse and inconclusive (e.g., Neece et al., 2013), we suspect that interaction is important for all planetariums and all kinds of shows or lessons, and for both cognitive learning goals and affective (motivational) learning goals. This is a reasonable expectation if we follow Slater and Tatge (2017), who proposed that the transformation of planetariums to "...a useful tool in the broader science teaching portfolio [...] occurred when planetarium educators were able to appropriately adopt the educational theory-driven and research-confirmed practices into science teaching, and incorporated these into the planetarium learning environment." (p.70). Essentially, we think planetarians need to engage with ideas and concepts from science education research. This is true for working with the general public but certainly also for school groups given that curricula around the world are to an extent including these topics in astronomy and space sciences (Salimpour et al., 2021a, 2024b). As such, this current study explores the type, nature and prevalence of interactions between planetarians and their audiences.

However, the planetarium is not like compulsory education. Planetarium visits are typically short and singular (i.e., not repeated (Cardin and Sermeus, 2024)). This means that interaction, for example, in the form of feedback, can be expected to happen less often or to be less extensive in a planetarium context compared to compulsory education (where tests can be taken) (Neece et al., 2013; Shaby et al., 2025). Moreover, there are physical constraints that make planetariums different to other out-of-school educational settings. The dome is dark, which might reduce interactions other than verbal between visitors or with the planetarians (Neece et al., 2013). The dome is often accessed through a single door or corridor that might make visitors feel rushed to leave (Shaby et al., 2025), possibly reducing interaction after the show. The dome is a shared screen for all visitors, who are guided by the planetarians through the same teaching (or communication) sequence (though this of course does not imply that all visitors have the same learning experience). This might limit the individual visitor-planetarian interactions (Stepanovic et al., 2024). Therefore, even though planetarium professionals favour live interactions (Small and Plummer, 2010), the question arises if, how and to what extent planetarians interact with their visitors.

3 This study

Planetariums have been engaging in out-of-school science education for a century (International Planetarium Society, 2023). There has been some educational research investigating the distinct context of the planetarium. However, this research has been geographically limited (despite the global planetarium community), and sparse compared to other cognate fields of education. Yet, insights from educational research in the setting of planetariums can be of interest to researchers in both

1 The work in the planetarium, certainly with regard to the general public, can be categorised under the umbrella of science communication. While science communication has been a practice that scientists have done since the mid-19th century, it has only recently emerged as a field of research (Trench and Bucchi, 2010). The early findings from science communication research are in line with (science) education research literature (Baram-Tsabari and Osborne, 2015). Indeed, here too interaction is desirable, as expressed in the movement from the so-called deficit model of science communication to dialogue and participation models.

other informal and compulsory education settings (in addition to the planetarium community, of course). Comparing the planetarium with education in schools and with other out-of-school science education settings will allow the school/out-of-school and formal/informal variables to be characterised, this will allow researchers to test elements and aspects of education (e.g., gestures, interaction, feedback, representations etc.) and theoretical frameworks (e.g., Pedagogical Content Knowledge, instructional design, conceptual understanding through various theoretical lenses etc.). Moreover, the planetarium is both stable (i.e., similar content and teaching across groups) and extreme (i.e., in a setting of low interaction due to the darkness and short singular visits). The planetarium could thus serve as an ideal testing ground.

To allow such comparisons between planetariums and other educational contexts, it is imperative that we have a global perspective on planetariums and the planetarians. This study aims to provide a step in progressing towards a global understanding of planetarians and revitalising the global perspective of the field of planetarium education research. The aim of this study is to paint a global picture of the planetarians' personal identity, professional identity, extent of interaction, and the range of topics presented in the planetarium. This study asks the following overarching research questions:

- **RQ1:** What are the descriptive demographics of planetarians globally?
- **RQ2:** How and to what extent do planetarians interact with their audiences (general public and schools)?
- **RQ3:** What characterises the professional identity of planetarians?

4 Methodology

To answer these questions an online survey was constructed, translated, distributed, and analysed.

4.1 Survey construction

The development of the survey questions drew in part on the guidelines set out by Adams and Wieman (2011) and the work of Schultz and Slater (2020). Given the international scope of this current study, the aim was to ensure that questions were explicit enough to allow translations to reflect the essence of what was being asked, whilst ensuring that the length of the survey would keep attrition to a minimum.

The survey was built in Qualtrics, and consisted of 81 questions, which are broadly grouped into the three overarching themes: Planterian Profiles, Interactions & Content, and Professional Identity. To combat survey fatigue, we visualised the structure of the survey and, through branching, made sure participants only saw questions that were relevant to them. Still, 81 questions is a lot, so we checked survey statistics (e.g., completion times). Typical answer time was 20 minutes, but there were participants that took just over one hour (there were also much longer response times, we suspect they are from participants that paused). The survey contains various conditional sections, which are determined by whether the planetarians present to the general public and/or schools, and whether the planetarians show films and/or give live presentations. See Supplemental Material for the entire questionnaire.

4.1.1 Initial question construction in the three themes

The survey's flow was structured to address the connections between the three themes: demographics, professional identity and interactions (Fig. 1).

Within these themes, finer-grained lines of inquiry were explored that allowed the characterisation of planetarians globally.

Planetarian Profiles This theme explores the planetarians as individuals. The research questions driving this theme included:

- What is the gender distribution of planetarians globally?
- What are the educational and career background(s) of the planetarians?
- What are the personal and professional interests in astronomy of the planetarians?
- What roles and activities do the planetarians take up in the planetarium?

Questions in this theme were initially inspired by the work of Schultz and Slater (2020), and included typical demographic questions regarding age, gender, and educational/professional background. This section also included questions about the characteristics of the participants' planetarium (e.g., seating ca-

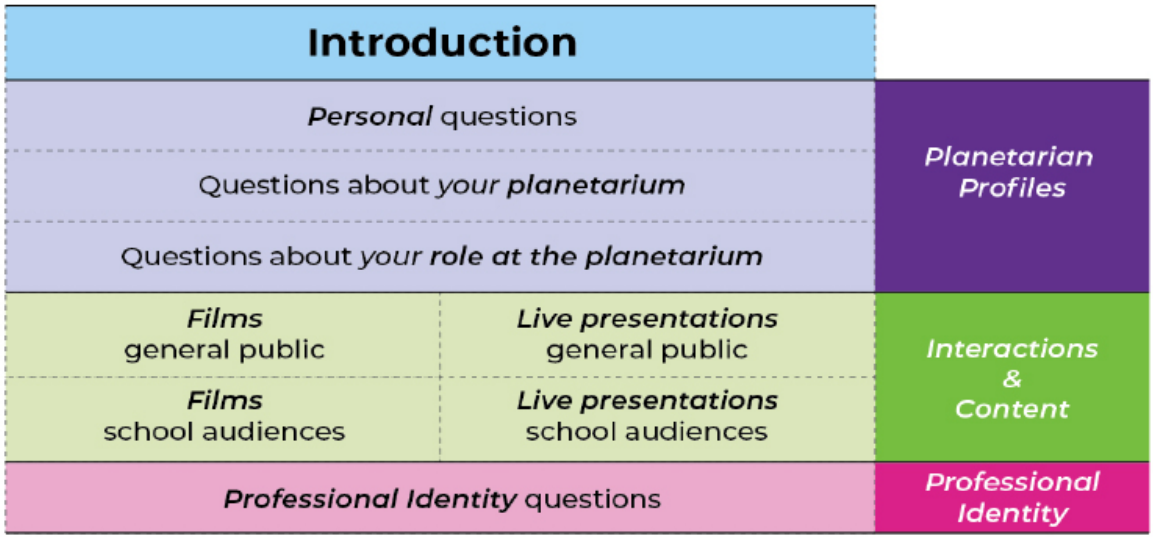

Figure 1. Visualisations showing the structure of the survey and the three overarching themes: Planetarian profiles, Interactions & Content, and Professional Identity

pacity, projection system) and the participants' involvement in the planetarium.

Interactions & Content The aim in this theme was to determine the nature and extent to which interactions are common practice in the planetarium when considering the diversity of cultural perspectives. Some of the questions driving this theme included:

- What is the nature of planetarian interactions with the general public and school visitors?
- What percentage of planetarium shows to the general public/school audiences are movies or automated sequences?
- What factors dictate the interaction?

The second aspect of any learning setting is the content being delivered. The aim for this research was to determine what differences exist between the content delivered in planetariums across the world:

- Which concepts and ideas from astronomy are presented and does this match curriculum standards (Salimpour et al., 2021a, 2024a) and the Big Ideas in Astronomy (Retrê et al., 2019)?

Questions initially developed were inspired by the works of Small and Plummer (2010), Plummer and Small (2013), and Everding and Keller (2020).

Planetarian Professional Identity The aim of this theme was to explore professional identity in the context of planetariums. To characterise this theme, ideas about engaging with literature, professional learning, and reflection were used:

- To what extent do planetarians keep up with research relevant to their practice?
- What is the nature of the research with which the planetarians engage?
- To what extent do planetarians engage in professional development?
- To what extent do planetarians transfer professional development (including their own experience) into their shows or presentations?

Questions initially developed were inspired by the work of Beijaard et al. (2000; 2004) and Canrinus et al. (2012), and touch on all six elements identified by Hanna et al. (2019).

4.1.2 Refining and validating the survey

Face validity of the survey was ensured by presenting the survey to two experts. One was a planetarium director (bringing expertise as a planetarium professional), the other an astro(physics) educational researcher (bringing methodological expertise). Based on their feedback, questions regarding interaction with the audience and teachers were also included in the survey.

In order to get confidence in the construct and content validity of the questionnaire we presented the survey in think-aloud interviews to active planetarians from different continents (Asia, Africa, Europe and South America). Minor revisions were implemented based on their feedback, which included vocabulary, grammatical changes, changes to improve the clarity of the questions by adding examples and some changes to the question types (from being able to select one answer in a multiple-choice question to selecting multiple answers). For example, we indicated in the introduction that the survey should be completed for the planetarium under "normal" operating periods, i.e., not for the way it was running during the COVID-19 pandemic.

4.1.3 Translations

To get a representative global picture it was important to be able to offer the survey in languages other than English. The International Astronomical Union's Office of Astronomy for Education (IAU OAE) has a network of individuals active in astronomy education. This network at the time of the research was made up of over 350 National Astronomy Education Coordinators (NAECs) representing 110 countries (IAU Office of Astronomy for Education, 2023). A questionnaire was distributed within the NAEC network to determine in which countries/regions an English version would be appropriate; overall, in most cases English was acceptable (indeed most participants answered the English version, which was set as default). We also looked at the distribution of languages around the world, this allowed us to determine which languages the survey would need to be translated into to provide maximum reach. In the end by enlisting NAECs and individuals beyond the NAEC network, we were able to translate the survey into 11 additional languages: Arabic, Brazilian, Chinese, Dutch, French, Japanese, Korean, Polish, Portuguese, Russian and Spanish (see Acknowledgements).

The translation process was the same for all partners. They received a digital copy of the English version of the survey as well as the informed consent form. The partners translated the questions in the survey and the informed consent form into their native language. The authors integrated the translation into Qualtrics, after which the translation partners were again invited to review the survey in Qualtrics to ensure that all translations were implemented correctly. This process was repeated until the translators were satisfied with the translation.

4.2 Survey distribution

The aim of this research project was to have a global reach. To achieve this aim, we selected three channels for distribution: the International Planetarium Society (IPS) newsletter, direct distribution to regional planetarium associations, and through the IAU OAE NAEC network.

Figure 2 shows the number of participants per country; specifically, they were asked where the planetarium they work at was located. We reached planetarians from 46 countries and from all continents (except Antarctica, where there are no planetariums). Planetariums are not evenly distributed across the world (WPD, 2021). There are, many planetariums in the USA, Japan, Korea, but very few in the continent of Africa. This distribution also emerges in our map. The survey was completed mainly in English. Our efforts to translate the survey and reach people in other countries was useful, given that Spanish, French, Portuguese, and Russian, are languages that are spoken in many countries. This supported us in getting responses from these language communities. Korean and Japanese were also languages that were often used due to the large number of planetariums in these countries. Arabic, Dutch, Polish, and Chinese were used much less.

5 Analysis and Results

A mainly quantitative approach was employed to the analysis, with descriptive statistics (Cohen et al., 2011). The number of respondents that attempted the survey was 589. After cleaning the data using a custom python script based on the work of Salimpour (2021b), the number of completed responses was 305. The Python script automatically cleaned the raw data (e.g., removing blank and incomplete responses, extraneous columns), calculated counts and percentages for various ques-

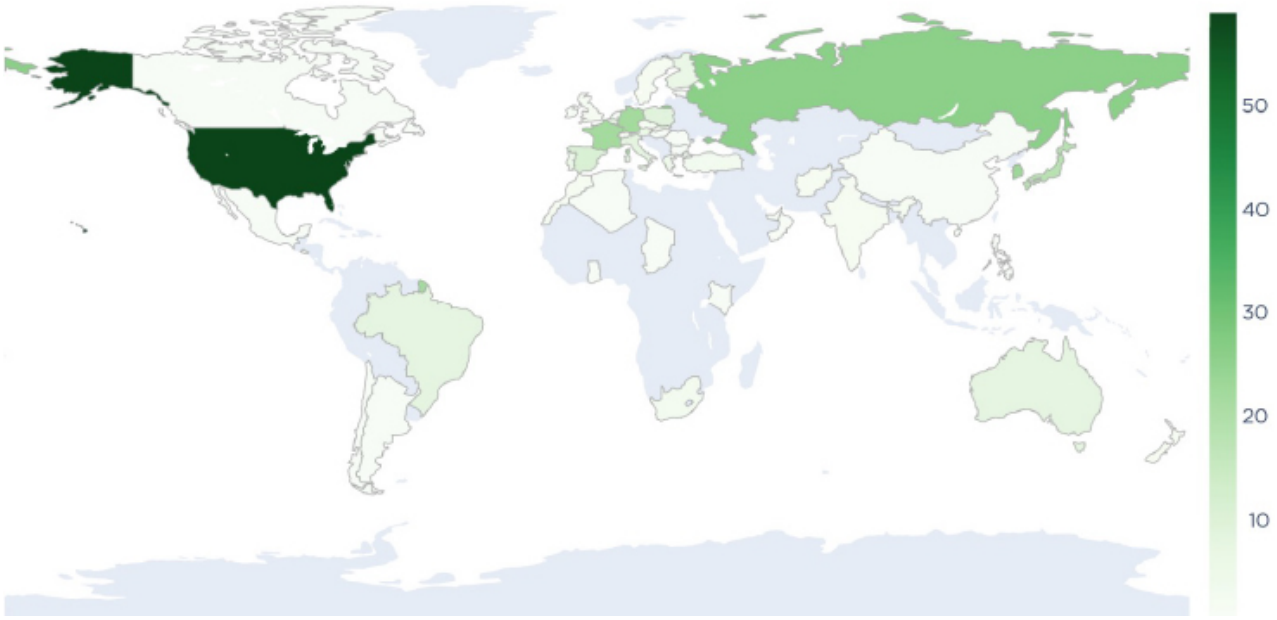

Figure 2. Visualisation showing the global reach of the survey to planetarians. The colour indicates the number of participants

tions, and generated visualisations. This enabled consistent and repeatable analysis to be run even when new data was added.

5.1 Planetarium characteristics

While not the focus of this demographic survey, we were interested in the planetariums the planetarians worked at to be able to draw correlational conclusions.

In Figure 3 we mapped the seating capacity of the planetariums with the number of visitors to a typical show. What is clear from this chart is that if a planetarium is small, it is likely often filled up (> 80%), if it is very large it typically has a lot of empty seats. A planetarium with an intermediate size seems to find a nice middle ground. Basically, large planetariums are huge infrastructures that are (much) more expensive to build, to maintain, to operate compared to small planetariums (certainly mobile planetariums). Large planetariums offer more seats and are thus able to accommodate larger groups (getting astronomy to more people), but in practice seem to mostly not operate at full capacity. On the other hand, small planetariums typically operate at full capacity, but perhaps there might be more demand. As such, planetariums of intermediate size seem to strike a good balance between cost, efficiency, and capacity.

The planetariums that participated were predominantly fixed constructions, 85%, of which 26% also have a mobile planetarium (22% of all respondents). Only 12% of the planetariums that participated were fully based in a mobile dome, this is in line with what we find in the World Planetarium Database. The domes of the participating planetariums are also predominantly not tilted, 27% had a tilted dome. The planetarians work in a planetarium with an optomechanical projector (38%, only 9% has only a mechanical projector, others are hybrid systems), a central digital projector (35%) and/or several peripheral projectors (54%).

While many planetariums are organisationally independent, many are also affiliated with another institution, see Table 1. While we anticipated many larger institution types, the one that came up often as 'other' was the planetarium as part of a city or municipality.

Table 1. Participating planetarium associations (single choice answer)

Organisational context of the planetarium	Counts
The planetarium is independent.	67
The planetarium is part of a larger science center.	55
The planetarium is part of a museum.	49
The planetarium is part of an observatory.	42
The planetarium is part of a higher education institute (university or college).	38
The planetarium is part of a school (primary or secondary education).	13
Other (part of the city, an institution that combines several of the above, adult education center,...)	34
Blank	7

5.2 Planetarian Profiles

5.2.1 General Descriptive Statistics

In this section we look at individual planetarian profiles to get a picture of the planetarian demographics.

5.2.1.1 Gender, age and experience Overall, the gender distribution is 67% male, 32% female with a few planetarians (<1%) indicating they identify as non-binary or a third gender. The latter will, whenever we make a distinction with respect to gender, not be reported on in this study due to the small sample and possible privacy issues. These numbers are in line with the Culture and Climate report of the IPS (Schmoll et al., 2021). The representation of women in planetariums is similar to that of women in astronomy as reported in the IAU's member statistics (21% of all members and 33% of junior members are female, IAU website 2025).

The age distribution is roughly gaussian, with most operators aged 26-55. However, as shown in Figure 4, it is clear that this distribution is not the same for both genders. Male planetarians are typically older than females (48.2$\pm$13.3*formales*, 40.8$\pm$13.3*forfemales*). A Mann Whitney U-test confirms that the two gender groups are indeed significantly different ($p < 0.001$).

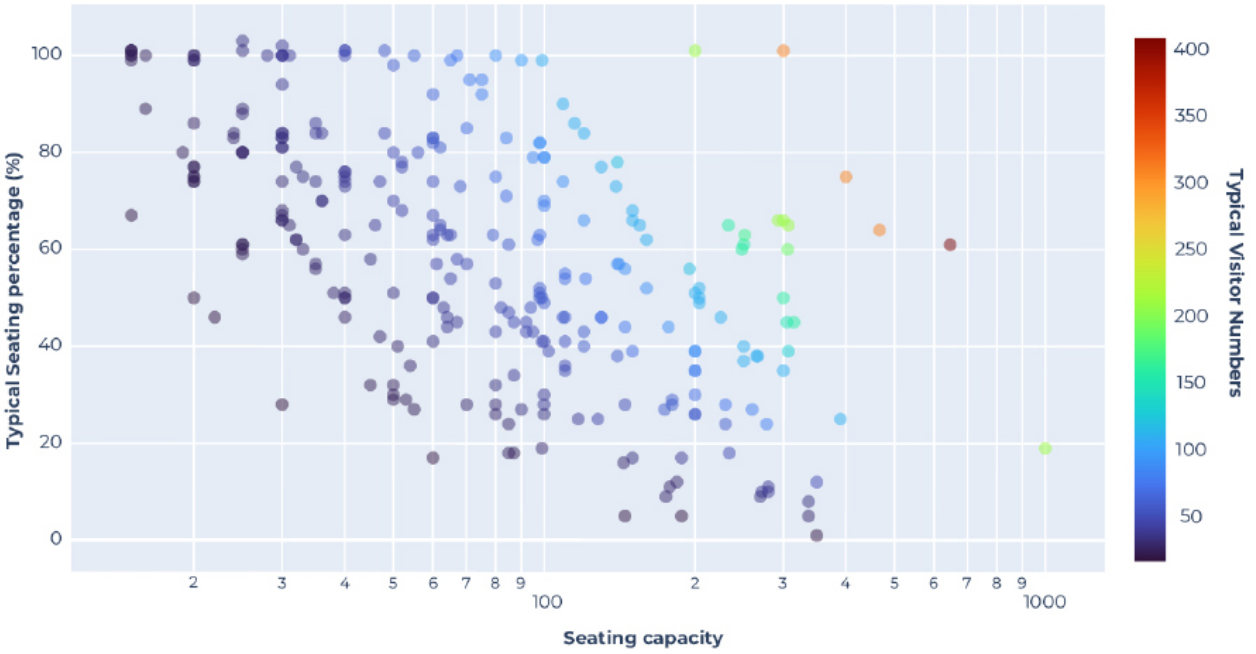

Figure 3. Seating percentage as a function of seating capacity of the planetariums where participating planetarians work. Seating percentage is the ratio of typical visitor numbers and the seating capacity. Colours indicate typical visitor numbers. A small amount noise (jitter) was added to the seating percentage to distinguish overlapping points.

Comparing planetarian experience and their age we find that in general older planetarians have more experience, which is not surprising. But there is also a group of male planetarians of ages 46-55 with less than 10 years of experience, see Figure 5. If we look at these profiles in more detail, we see that these are people that are typically not volunteers but work at the planetarium in a full-time job, and that they made a career change because they are interested in science, astronomy, and/or teaching. Of the planetarians 70% work as full-time employees and 12% are volunteers (a significant group that planetariums depend upon).

5.2.1.2 Educational background Most planetarians have a higher education degree (90%). Those that do not have a degree in higher education are mostly male (84%), and of all age groups. This is in line with findings by Schultz and Slater (2020).

Figure 6 shows the field in which participants obtained a degree in higher education (Bachelors, Masters, or PhD). It is clear that most have a background in STEM (Science Technology, Engineering and/or Mathematics), with physics and astronomy standing out as obvious degrees. Another significant group are those with a degree in teaching or educational sciences. Finally, we find that only 5% of the participants have a degree in the performance or visual arts. This is a much smaller number than Schultz and Slater reported in their study. They found that 30% had "previous experience as a performer of some kind". The difference may be due to the difference in geographic focus or methodology, it may also be because experience is not the same as obtaining a degree.

We observe no differences in the educational background of male and female planetarians with degrees in STEM, see Table 2 where we separated planetarians that had, in addition to a STEM degree, also another degree (multiple answers were possible).

5.2.1.3 Career background About 1 in 3 planetarians have previous career experience in teaching and 1 in 5 have experience in astronomy research, see Figure 7. A much smaller number have experience in other types of research, engineering, and of working in a museum. These observations are independent of gender.

Table 2. Gender differences in educational background of planetarians.

	% of total males (N=206)	% of total females (N=96)
STEM and nothing else	54	50
STEM and teaching	17	17
STEM and creative arts (visual & performance)	2	1
No STEM	28	32

The questions asked in the survey did not discriminate between full-time or part-time careers and multiple answers were possible. One year of experience may not be the same for all participants. Taken together, 65 out of 305 planetarians (21%) indicate that they have no other career experience.

5.2.1.4 Role at the planetarium Regarding the kinds of shows that the planetarians are responsible for, Table 3 shows how many of the planetarians present live shows and/or present films to the general public and/or school groups. The results show that the largest group present live presentations (and films) to both the general public and to school groups. The numbers in Table 3 are also an indication of the number of participants who completed various parts of the survey.

5.2.1.5 Interest in astronomy As part of understanding the profiles and demographics of the planetarians we wanted to determine their interests at a personal level in astronomy. Participants could select multiple options from a list (see legend in Figure 8). The distribution for the different interests of planetarians in the context of astronomy, for each of the age groups is shown in Figure 8. Planetarians of all ages look up at the night sky, read books about astronomy or science in general or they

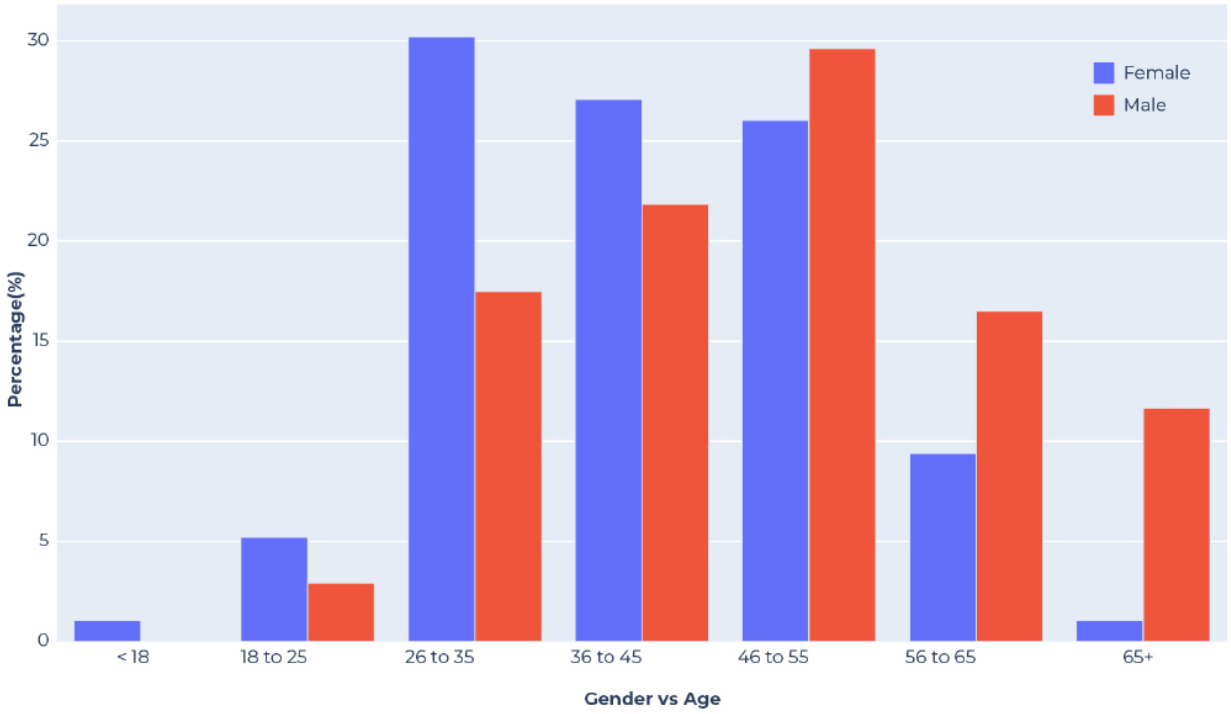

Figure 4. Age distribution (male planetarians in red, female planetarians in blue)

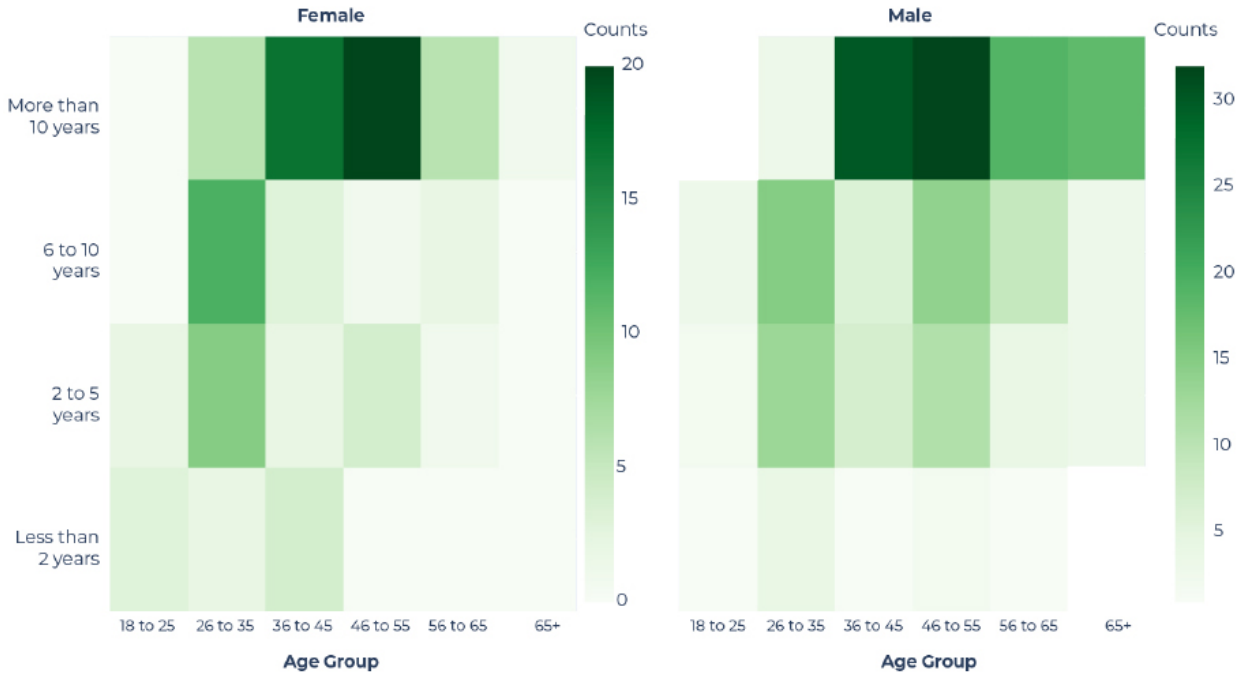

Figure 5. Age vs experience heatmap (female left, male right)

Table 3. Responsibilities of participating planetarians. GP: General public, SA: School Audiences

	Full-dome films only	Live presentations only	Both films and presentations	Blanks	Total
General Public only	2	7	17	-	26
School groups only	1	5	13	-	19
Both General Public and school groups	GP: 16 SA: 17	GP: 63 SA: 68	GP: 148 SA: 136	GP: 1 SA: 7	228
Neither	-	-	-	23	23
Blanks	-	-	-	9	9
				Total	305

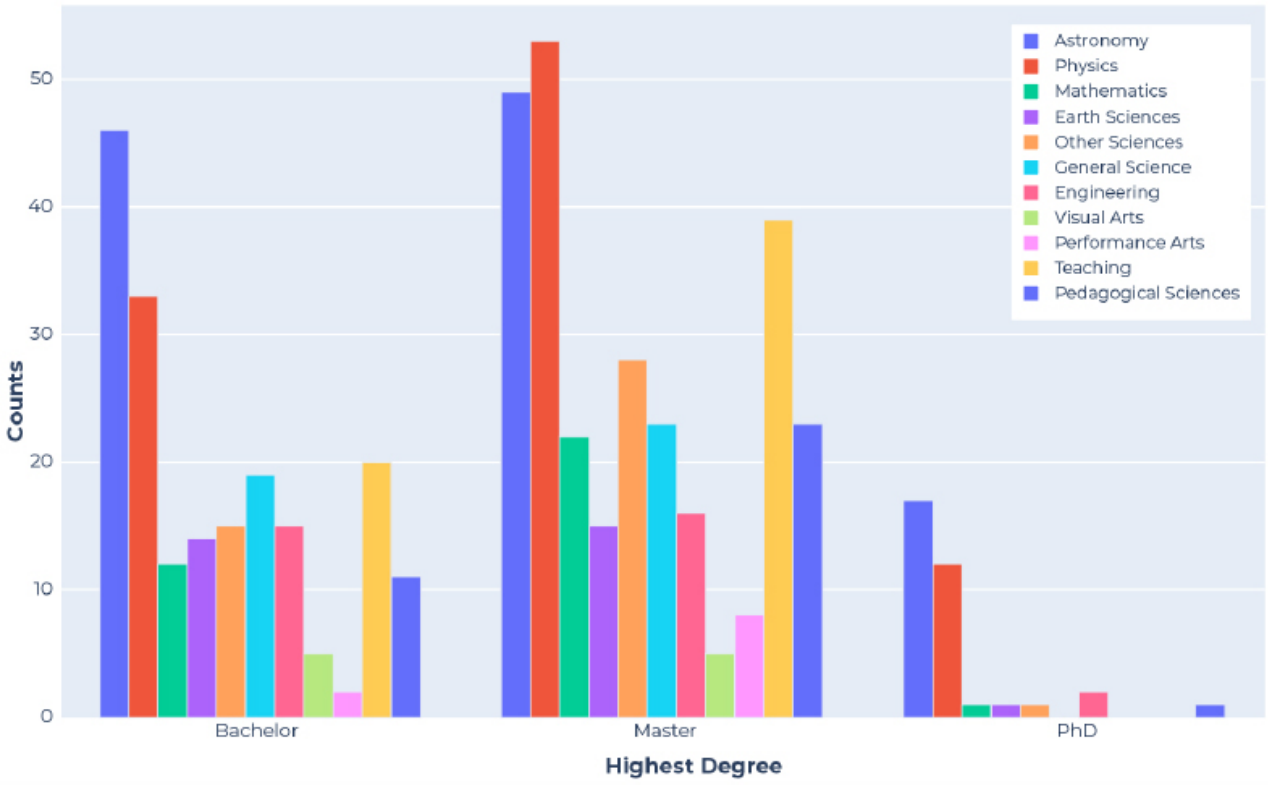

Figure 6. Distribution of degrees in higher education

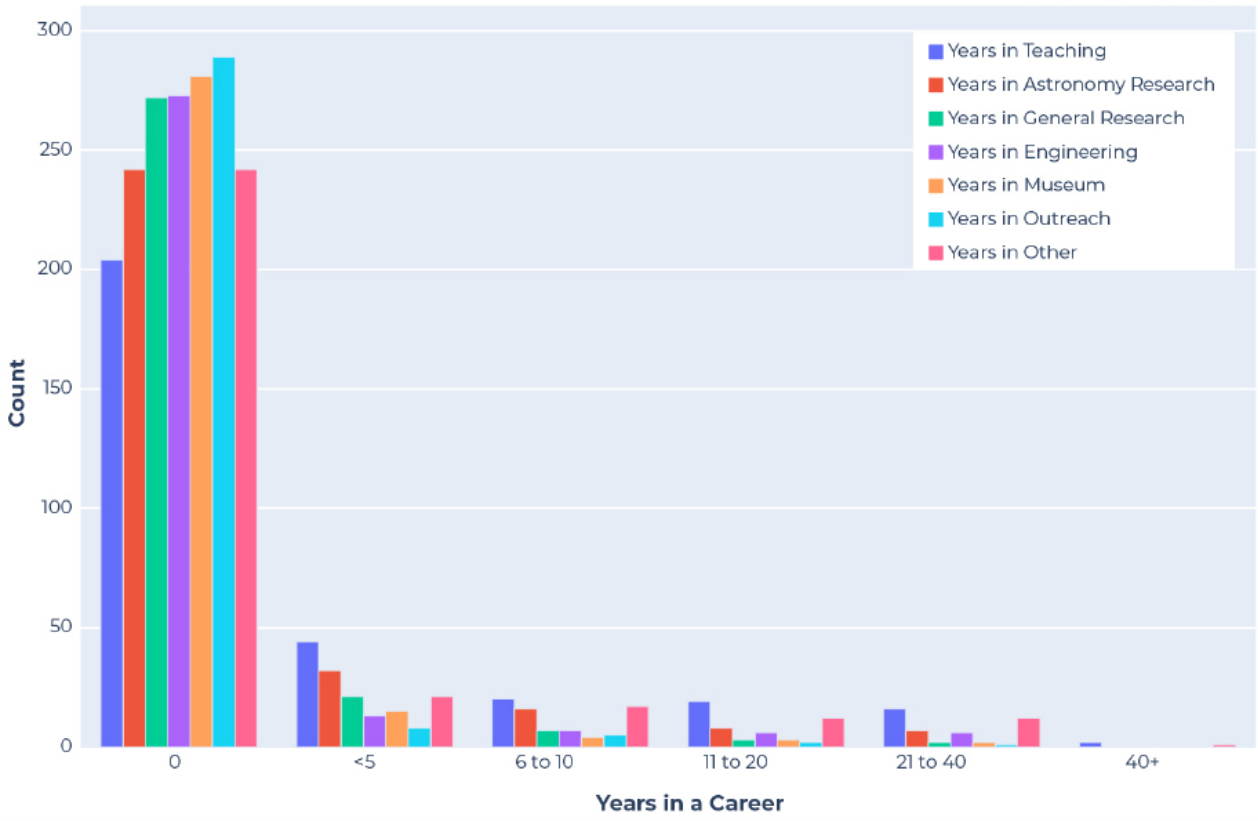

Figure 7. Years of experience in other careers.

follow night sky events (like conjunctions). A smaller group has at least one telescope at home or does astrophotography. That this is a smaller group is likely because this requires investments and resources. Looking at the age groups, it can be seen that younger planetarians (<25 years old), seem to be less interested in the History and Culture aspect of astronomy, and that they are less likely to follow Night Sky Events.

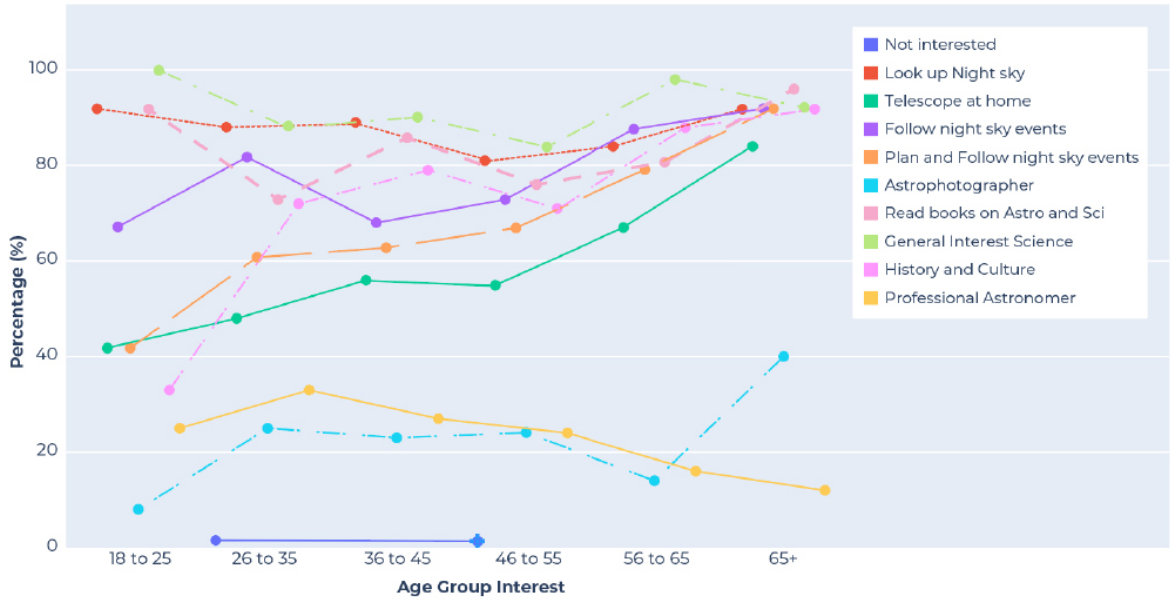

Figure 8. Planetarians interest in astronomy binned by age group.

5.3 Interaction and Content

5.3.1 Interaction with the audience

Figure 9 shows that there is almost always some interaction with the visitors if there is an element of live presentation in the planetarium show. Roughly 50% of planetarians interact before, during and after the shows with their audience, and less than 10% never interact with their audience. Note that Figure 9 does not provide any insights about the level of interaction.

Looking at Figure 9 it is evident that there is less interaction before the start of the presentations, there is more interaction with the audience during presentations if they are fully live, and presentations that have both live and automated elements favour interactions before and after the show (compared to others). Finally, there seems to be less difference between general public and school audiences than between fully-live and in-between shows.

Figure 10 shows that most of the interaction is verbal, and as noted previously there is no real difference between the general public and school audiences.

Figure 11 shows the interaction with the teachers. Typically, before the visit there is interaction regarding practicalities (time of arrival, number of visitors, parking,…), during the visit teachers are part of the audience, maybe managing the group, and finally the interaction is limited to what happens immediately after the show in the planetarium. Overall, the interaction is quite limited.

5.3.2 Content

Figure 12 shows the topics that are presented to the general public and school audiences. One insight from this analysis is that "traditional" astronomy topics (celestial motion, constellations and planetary science, including our solar system) are presented more often than contemporary issues and topics in astronomy (e.g., astrobiology, cosmology, instruments, exoplanets, extragalactic astronomy). A closer look reveals that traditional topics are more often presented live, whilst contemporary topics are more often shown to audiences through films. A second observation, one we have made throughout this paper, is that there seems to be less difference between general public and school audiences, here compared to the difference between films and live presentations.

Table 4. Percentage of planetarians that discuss or introduce elements of astronomical history or culture in their shows. These percentages are calculated by normalising the numbers for each combination (e.g., number of people presenting to GP that are not interested in history and culture (57) that do include elements of history in their presentation (21) results in 21/57=37%).

History & Culture	not interested in history and culture	interested in history and culture
presentations to GP	37% & 32%	61% & 72%
to school audience	31% & 31%	56% & 61%

Presenting content on the historical and cultural aspects of astronomy is overall a topic that is not often addressed. As noted earlier, planetarians within the higher age groups are more likely to be interested in the history and cultural aspects of astronomy. And hence, not surprisingly, when planetarians are not interested in the history and culture they are less likely to discuss it in live presentations to the general public or to school audiences, see Table 4.

Given its relevance in the community the list of topics that was presented to the participants is compared to the Big Ideas in Astronomy, see Table 5. The Big Ideas in Astronomy document provides a guide to the topics that an informed citizen should know about astronomy (Retrê et al., 2019). The document created through an iterative process via the astronomy and astronomy education communities contains 11 overarching Big Ideas, each with its own set of sub-ideas, for a total of 97 ideas. Most ideas are present in the list we presented, though Big Idea 11 was not included. Inversely, we included Space Exploration as a possible topic.

5.3.3 Goals of films

Finally, we were interested in what planetarians think the goals of presented films are, both for the general public and school audiences. We did not ask this question for live presentations. The results are presented in Figure 13, where we grouped items

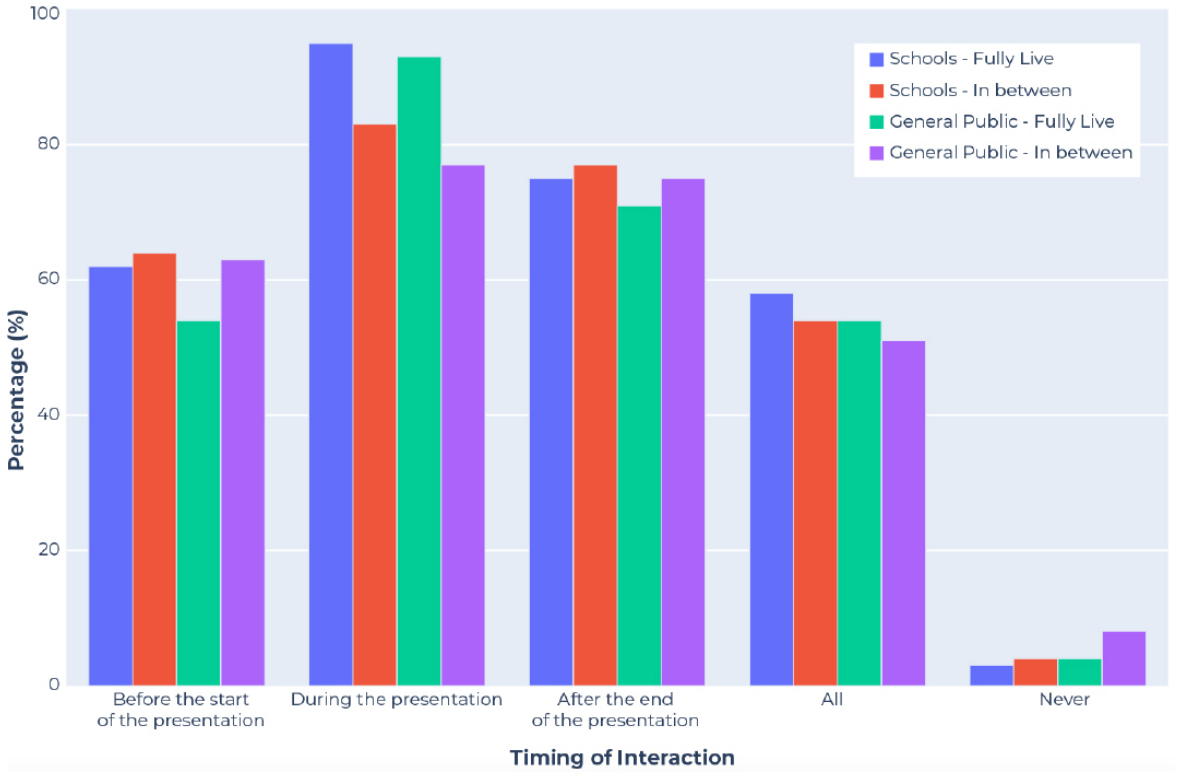

Figure 9. Interaction timing vs automation level. Note participants could indicate multiple answers. There is a large group that selected all (before, during and after), they are thus also part of the before, during and after group.

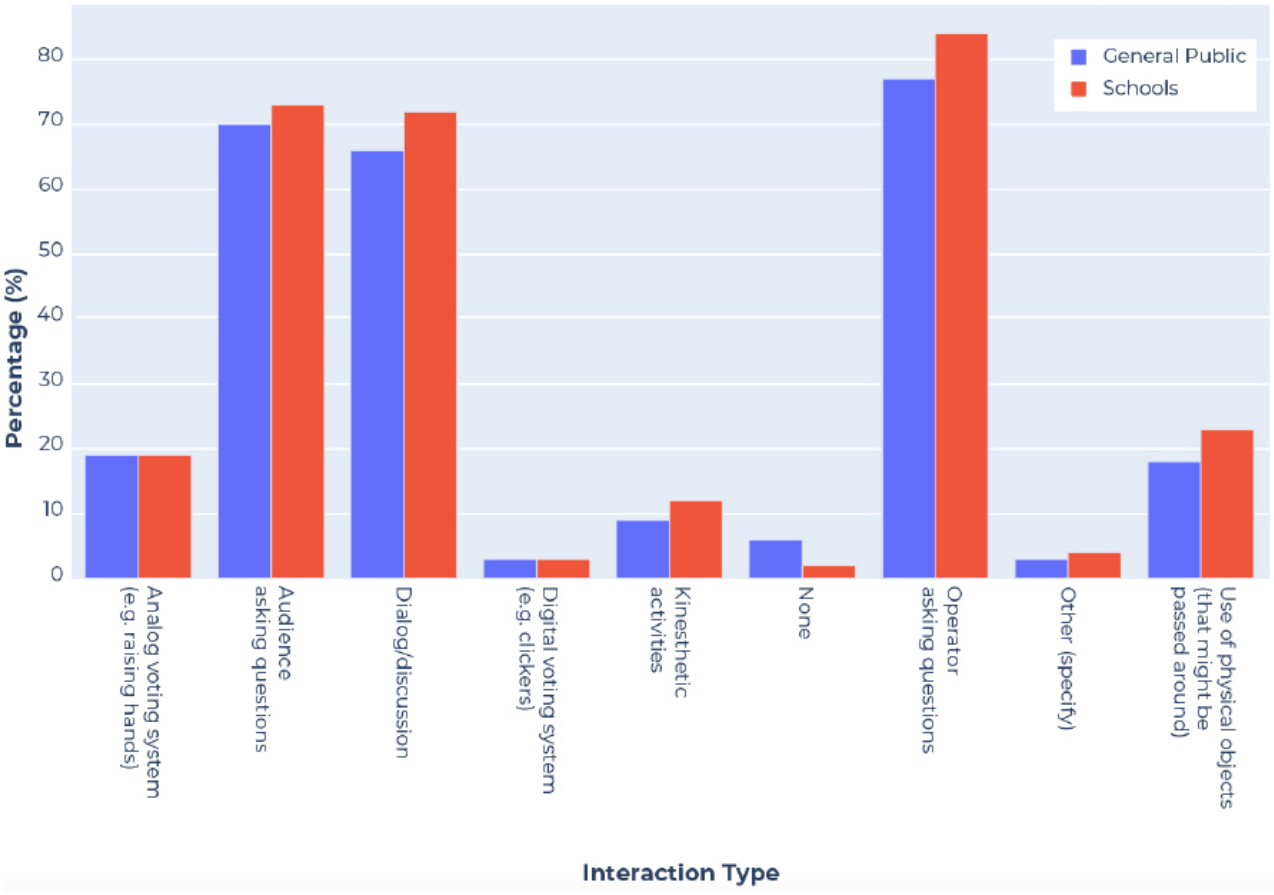

Figure 10. Comparing the different forms of interaction planetarians engage in with the general public and school audiences.

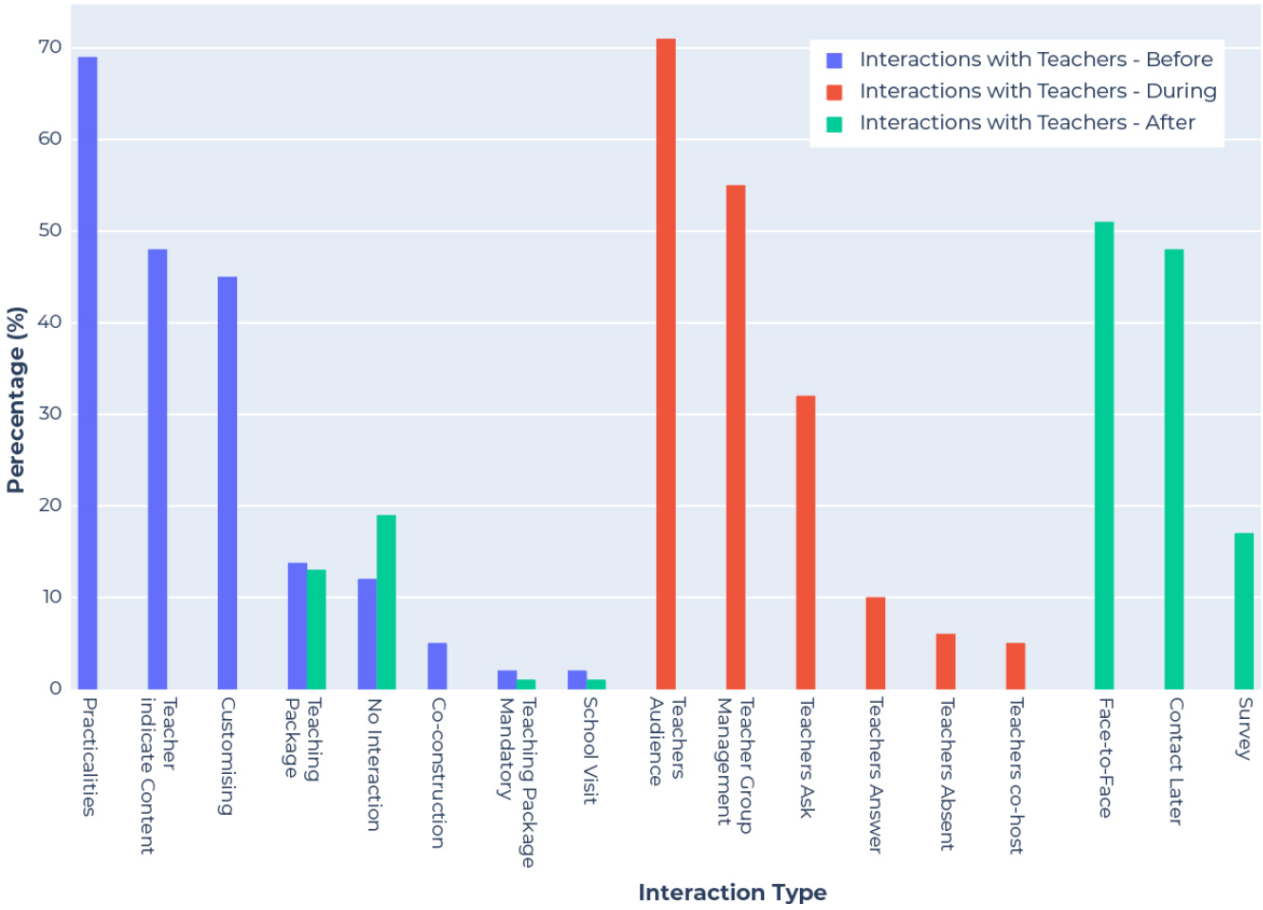

Figure 11. Comparing the different interactions with teachers before, during and after a visit to the planetarium. "Teaching Package" refers to a preparatory or post-visit course material that the planetarium provides for visiting teachers.

Table 5. The alignment of the astronomical themed planetarium shows to the Big Ideas in Astronomy.

Planetarium Topic	Big Idea	Big Idea Statement
Astrobiology (Life, extra terrestrial intelligence,…)	10	We may not be alone in the Universe
Astronomy instruments (radio telescopes, space-based telescope, gravitational wave detectors, EM-spectrum,…)	5	Astronomy benefits from and stimulates technology development
Celestial motion (Motion of the sun, stars, moon, planets,…)	2 & 3	Astronomical phenomena can be experienced in our daily lives The night sky is rich and dynamic
Constellations	1	Astronomy is one of the oldest sciences in human history
Cosmology (Universe, Big Bang Theory,…)	6	Cosmology is the science of exploring the Universe as a whole
Exoplanets (solar systems that are not ours)	10	We may not be alone in the Universe
Extragalactic (Galaxies, evolution of galaxies, gamma ray bursts, quasars, structure of galaxies,…)	9	There are hundreds of billions of galaxies in the Universe
Galactic (Milky Way, evolution of our galaxy,…)	9	There are hundreds of billions of galaxies in the Universe
History	1	Astronomy is one of the oldest sciences in human history
Culture (locally appropriate content, Indigenous sky knowledge)	1	Astronomy is one of the oldest sciences in human history
Nature of astronomy (observation rather than experiment, model development,…)	4	Astronomy is a science that studies celestial objects and phenomena in the Universe
Physics (gravity, relativity)	Mixed	
Planetary science (Solar System, moons,…)	7	We all live on a small planet within the Solar System
Recent advances in astronomy	5	Astronomy benefits from and stimulates technology development
Seasons (Earth-Sun system, axial tilt,…)	2	Astronomical phenomena can be experienced in our daily lives
Space exploration (NASA, Satellites, Moonlandings,…)	None	
Stars (Life cycle of a star, nuclear fusion,…)	8	We are all made of stardust
	11	We must preserve Earth, our only home in the universe.

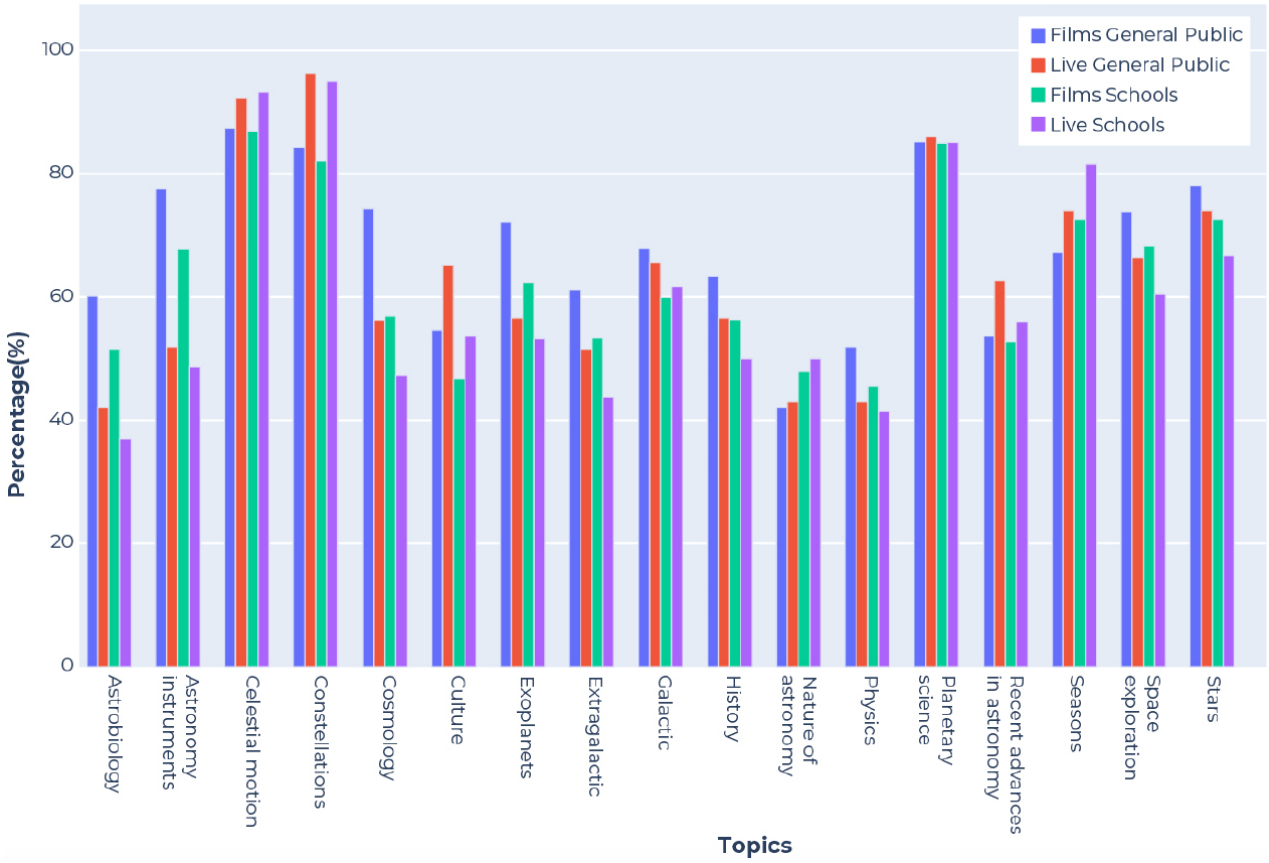

Figure 12. Content presented in films and live presentations to the general public and school audiences

related to entertainment and affective goals (interest, appreciations, etc.) and to cognitive goals (knowledge, reasoning, etc.). Planetarians think increasing interest, showing the beauty of the night sky, and entertainment are all part of the goals of the films they present in the planetarium. Planetarians also agree to statements about educational goals of planetarium films (e.g., to educate content, increase sky knowledge, educate or engage in scientific reasoning, offer an educational experience). However, agreement with educational statements is lower than for entertainment statements. For the general public the affective statements were chosen (relatively) 38% more often, but also (and surprisingly) for the school groups the affective statements were chosen 23% more often. Notably, planetarians do not think it is their goal to teach the curriculum (even if they are presenting these films to school audiences). As noted previously with other comparisons there is not a lot of difference between school audiences and the general public.

This slight preference for entertainment also came up when we asked for the planetarians' assumed expectations of planetarium visitors (regardless of whether they came to experience a film or a live presentation), see Figure 14. While most planetarians think that young students, adolescent students and the general public expect to be entertained, almost all planetarians think that teachers expect students to be educated.

5.4 Professional Identity

The survey questions that probe professional identity can be combined into six measures of the planetarians professional identity (questions 12.2-12.8 of the questionnaire, see Supplemental Material). The results below include all planetarians, full- and part-time employees as well as volunteers. The data for volunteers was inspected and was found to be in line with the rest of the data.

We started by asking a simple question, 'What motivates you to work in the planetarium?' (Fig. 15). In line with the planetarians' personal interest in astronomy, the results show that the top three reasons are 'Interest in astronomy', 'Interest in science', and 'Interest in science engagement/communication'. The question allowed respondents to select multiple options (statements), so there is overlap between these counts. A planetarian that is interested in astronomy will likely also be interested in science. A planetarian that is interested in either astronomy or science, will also be interested in science engagement/communication, which in turn often means that they are also interested in out-of-school educational settings or teaching. Science communication again comes first, and education is second. Convenience and financial reasons for working in a planetarium were by far the least chosen.

The second measure of professional identity is the planetarians' confidence in their own expertise. The planetarians were asked on a 3-point Likert scale whether they agree with the statements 'I have some expertise in teaching and learning' and 'I have some expertise in astronomy content'. We see that most planetarians have some level of confidence in their expertise in astronomy content and teaching skills, see Table 6. 18% are not confident in either teaching and learning or astronomy content, and 10% are not confident in either. Combined we see that more than a quarter of planetarians indicated not feeling confident in teaching and learning, astronomy content or both. This is a large group, indicating that planetarians might be interested or at least benefit from professional development. This group consists of planetarians of all ages, both genders, different countries, that present both films and do live presentations.

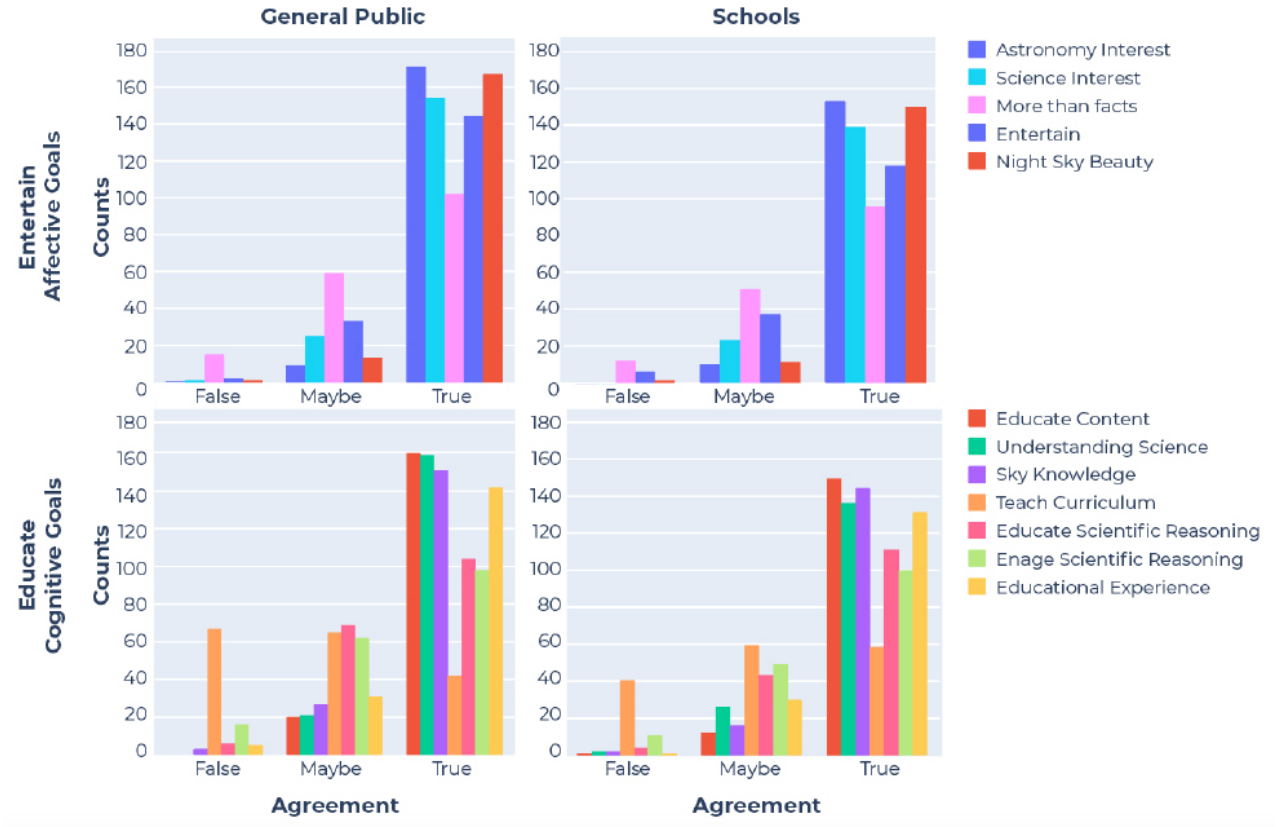

Figure 13. Comparing the Agreement to statements regarding the goal of the shows for the general public and school audiences. The statements have been categorised into those dealing with entertainment and those dealing with education.

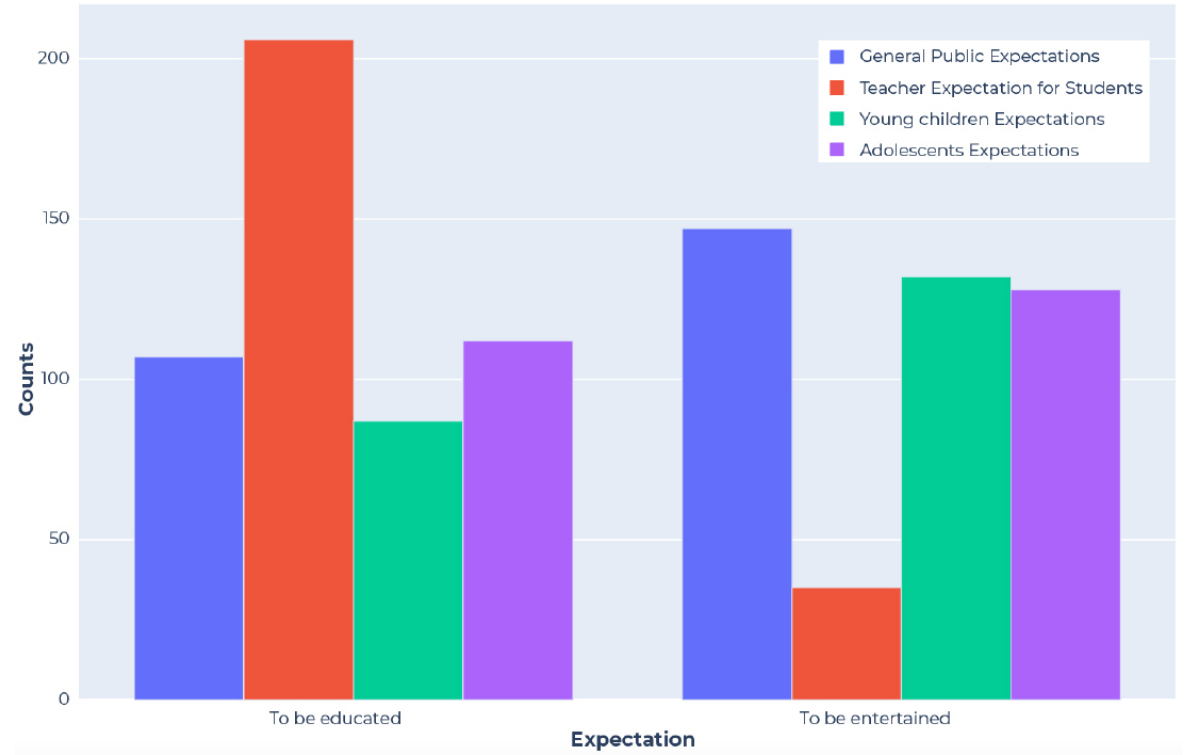

Figure 14. Distribution of what the planetarians think the expectations that different groups have of planetariums

Another aspect of professional identity is the degree to which planetarians are satisfied in their profession. We find that planetarians are, typically, happy (88%), regardless of their expertise. Very few planetarians indicate that they are not happy in their profession (5%), 7% were blank answers.

A third measure of professional identity are practices that planetarians undertake to progress in their profession. There are

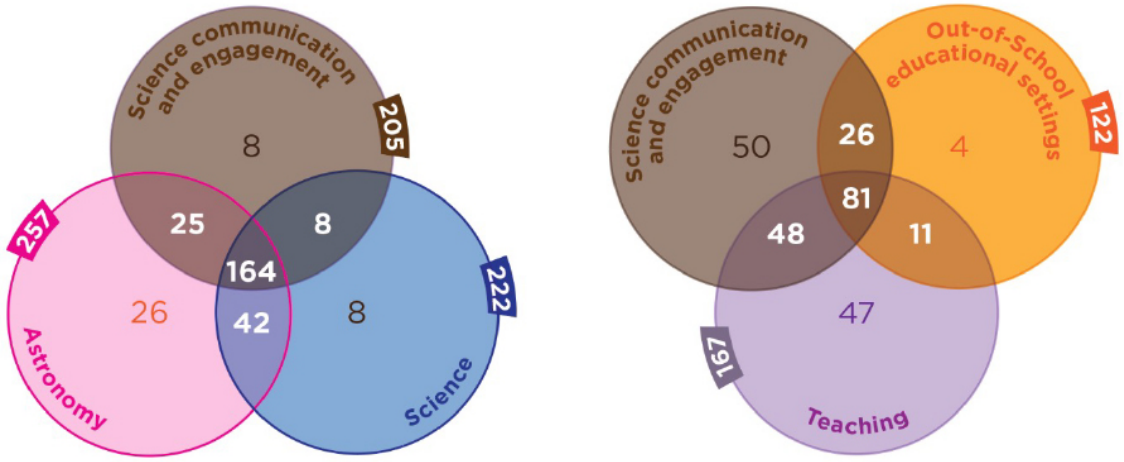

Figure 15. Overlapping reasons for working at a planetarium. Financial (48), convenience (e.g., located close to home) (36) and others (38) were chosen much less. 'Others' could be specified by the participants, for example: assigned/it's part of the job, interested in art/creativity side, interested in working with children, because the planetarium meant a lot personally.

Table 6. Agreement with the statements "I have some expertise in Astronomy" and "I have some expertise in teaching and learning"

	Counts
Some expertise in both astronomy content and teaching/learning	201
Some expertise in astronomy content but not in teaching/learning	17
Some expertise in teaching/learning but not in astronomy content	34
No confidence in own expertise in either teaching/learning or astronomy	28
Blank	25
Total	**305**

20 planetarians that did not select any form, see Figure 16. This means that most planetarians actively work towards improving their professional practice. Personal experiences, interactions with colleagues, and literature are the main divers for professional development. The extent to which planetarians follow literature is discussed in more detail below.

Personal experiences are often not accompanied by reflection. This raises the question how these personal experiences drive professional development. Alternatively, the wording of the question, the statement options and the sequence of statements may have resulted in less participants selecting this option. From this survey, it is unclear how participants interpreted the statement 'through personal experiences made conscious through (self-)reflection', and as such this may have had an effect on how they interpreted and answered the question: 'Through which of the following do you progress in your professional practice? Select all that apply'.

Asking feedback from visitors was questioned in more detail. Of the 305 planetarians, 85 indicated that there is no structured or formal procedure to gather feedback from visitors (with the aim of improving the shows). This aligns with reported lack of attention given to feedback and assessment by informal science educators (Busch et al., 2022; Erickson, 2021). However, many planetarians (nearly 70%) indicated that they do talk to visitors after the show, a practice that seems to be much more common than post-visit questionnaires (just over 20%). A likely explanation is that planetarians interact with visitors after the show to answer questions of visitors (i.e., not to assess their own actions). Other systems for gathering feedback are also used, though they are much less common, such as following internet reviews, using voting systems or contacting visitors/teachers after their visit through email or phone.

A fourth measure of professional identity is the extent to which planetarians follow advances in different fields of research. Based on the data we find that almost all planetarians follow advances in astronomy research, some exclusively through journal articles (2%) or popular media (29%), but most through a combination of both (62%). Of all respondents, only 1% indicated that they do not follow astronomy research (not through peer-reviewed articles, popular articles, TV programs or the news). 6% were blank responses. The percentage of planetarians following advances in research in science education, informal education, science communication or planetarium education is smaller (Table 77). 10% of planetarians do not follow any advances in any of these fields, for individual fields 22-24% do not follow advances in the field. Inversely, this means that approximately 90% of respondents follow research results in at least one of these four fields.

Planetarians follow advances in research through (a combination of) journals and/or conferences that can be practice-oriented or research-oriented. A large group engages with research in a more active way by attending practice- or research-oriented conferences on planetariums (36%), science education (28%), science communication (26%) or informal learning (21%).

A fifth measure of professional identity is receiving professional development. Approximately 40% of all planetarians between the ages of 25 and 65 (i.e., disregarding people that might be students or are retired) do not receive regular ("never" or "less than once per year") professional development regarding teaching or communicating astronomy. These individuals, similar to most planetarians, do follow astronomy research. Finally, and importantly, we asked planetarians the extent to which they integrate what they learned through reading, attending conferences, professional development or through personal practices. Planetarians indicated that they will change their presentation to incorporate new insights in astronomy, but to a lesser degree new insights in research in educational sciences. If anything, they are most likely to integrate insights in science communication, see Figure 17. This is another observation of planetarians thinking more about science communication rather than science education.

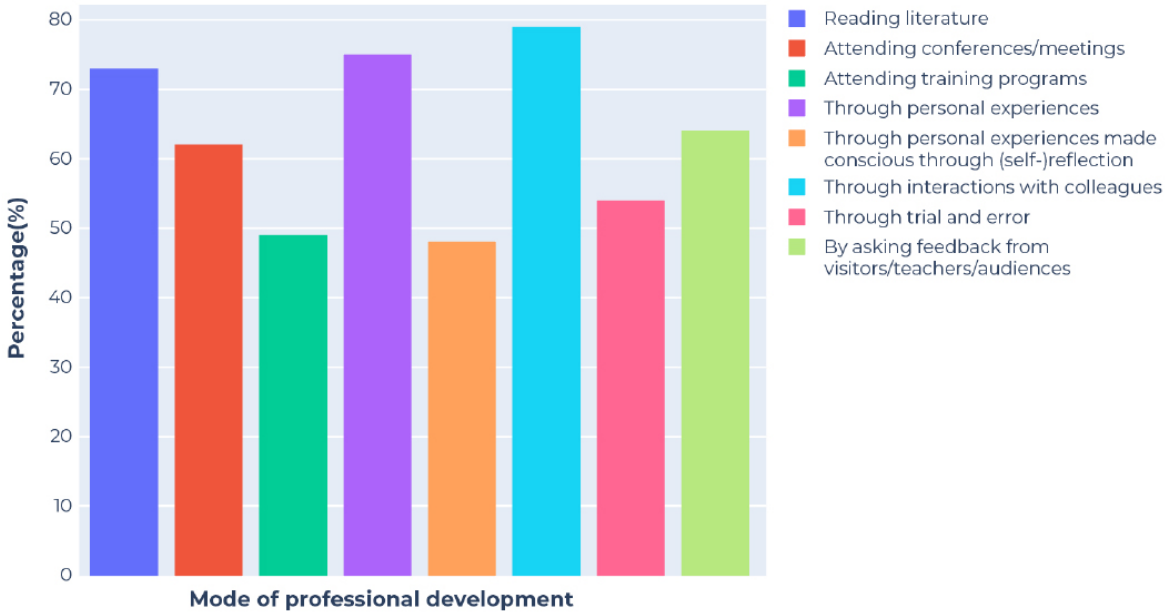

Figure 16. Comparison of the engagement of planetarians with various modes of professional development

Table 7. Comparison of percentage of planetarians and the various types of engagement with literature in science education, planetarium education, informal learning, and science communication

	Science education	Planetarium Education	Informal Learning	Science communication
Nothing	23	24	29	22
Practice oriented	30	29	28	29
Research oriented	13	11	10	11
Both practice and research oriented	27	29	23	29
Blank answers	7	7	10	10

6 Discussion

The questions in the survey provided a tool to quantitatively, albeit at a descriptive level, explore some complex, multi-layered themes, each of which is a construct that warrants deeper qualitative exploration in future research. Overall, the quantitative results provide some key global insights into the planetarians, their interests, motivations, and approach to professional development. Below we discuss the insights from each of the three themes and highlight some sub-themes that emerged from the analysis.

6.1 Planetarians

Planetarians are a heterogeneous group of all ages, with a range of educational and career backgrounds. Contrary to findings by Schultz and Slater (2020), we find that only a small fraction of planetarians have a theatre or performance background. However, other findings with regards to the demographics were in line with previous reports by Schultz and Slater (2020) and the IPS Climate and Culture Report (Schmoll et al., 2021). For example, in planetariums half of the planetarians do not have a background in physics or astronomy.

Here the emerging insights from research in out-of-field teaching (or Teaching Across Specialisations – TAS (Hobbs and Porsch, 2022)) may be of interest. From this literature, it is clear that teaching out-of-field/teaching across specialisations is quite common (Nixon et al., 2017), can be challenging (Hobbs and Törner, 2019), and can result in negative impacts on students' learning. This is obvious for teachers with a non-science background teaching a science course, but will also be challenging for, e.g., a biology major teaching physics (Crisan and Hobbs, 2019). After all, both disciplines are epistemologically different and have different ways of inquiring as well as different pedagogic traditions.

It seems likely that, similar to teachers in compulsory (formal) education, planetarians that do not have a background in astronomy or (astro)physics (out-of-field informal science educators) have the potential to inadvertently misinterpret the epistemology, ontology, history and nature of astronomy and (astro)physics. They may also lack the content knowledge necessary to develop pedagogical content knowledge. In other words, they might not be familiar with typical ideas of students, typical teaching traditions or the pedagogical and disciplinary affordances (Airey and Linder, 2017; Salimpour et al., 2021b) of typical representations in astronomy and (astro)physics. All this may lead to sub-optimal teaching (and learning) at the planetarium. Disciplinary affordance is defined as "The potential of a given semiotic resource to provide access to disciplinary knowledge" (Airey and Linder, 2017). Semiotic resource in this context is the representations. In essence, a student may have seen a representation for example of the Hertzsprung-Russell Diagram, or a redshift map of galaxies, but does not really appreciate the meaning that is only accessible with a certain level of disciplinary knowledge. On the other hand, out-of-field planetarians may enrich the international planetarium community by providing fresh ideas, alternative representations, pointing

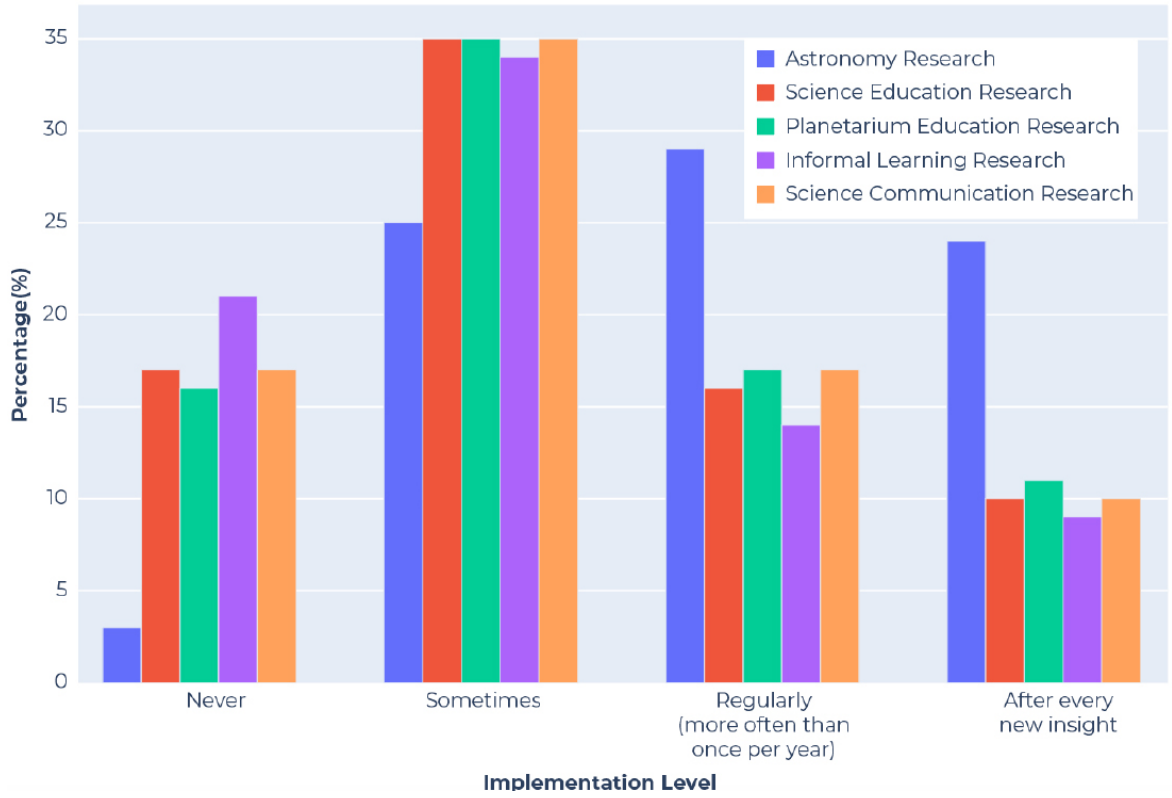

Figure 17. Comparison of how often planetarians implement research from various fields into their practice.

to connections with other fields or connecting with visitors in a different way. For example, data visualisations can be used to learn about astronomy (e.g., Eriksson et al., 2014; Salimpour et al., 2021b; Subramaniam and Padalkar, 2009). It is thus not clear, and should be the subject of further research to determine whether the diversity of backgrounds of planetarians is a liability or an asset.

6.2 Interactions and Content

6.2.1 Role of interaction

As mentioned earlier, both teacher-student and student-student interactions are important. They allow teachers to probe prior knowledge, tap into and revive prior ideas, check student progress, and evaluate the extent to which their pedagogical approach was effective in addressing the aims of the lesson. As experienced educators we know that interactions can challenge students to think deeply and critically, can improve the uptake of new knowledge and skills, can stimulate the assimilation of the newly acquired knowledge into existing mental structures, allow to express doubt and open the lesson for asking questions. It is positive to see that planetarians value interaction as it is an important aspect of education.

During a show we see that interaction is predominantly verbal, in the form of discussions and questions & answers (Q&A). The dominance of verbal interactions is not surprising, the planetarium is after all a dark place, which limits the use of gestures, analogue voting, kinaesthetic activities, and other forms of interaction that require participants to be able to see each other. However, we expect that it should be possible to interact with audiences using other modes besides Q&A and discussions (e.g., kinesthetics, physical models,… (e.g., Christian et al., 2024; Plummer, 2009; Rollinde, 2017). We should note that there is also the consideration of whether the audiences consist of those with a disability that prevents certain types of interactions.

There is an opportunity to expand on this work in a global context, to investigate other possibilities of interaction, and characterise the barriers inhibiting planetarians from interacting with audiences (and teachers in preparation of visits). Furthermore, the data in this research is limited in that we did not probe the quality and quantity of this interaction, which warrants a deeper study focussed on this aspect.

A striking result is that there is also limited interaction (less than half) with teachers before or after a visit. There is even less interaction with teachers in the form of teaching packages (preparatory or reflective). There are real opportunities to increase the value of a planetarium visit by adding a pre- and post-program similar to other field-trips (e.g., Behrendt and Franklin, 2014; Lee et al., 2020; Post and Molen, 2014). Of course, teachers might very well prepare and process planetarium visits, something we did not check with teachers and where additional research is needed.

We propose that the construct of interaction is to a degree influenced and connected to Pedagogical Content Knowledge (PCK) (Shulman, 1987). The results of this study provide a start in beginning to unpack this in the planetarium setting. Busch et al. (2022) introduced the idea of informal science educator PCK (ISE-PCK) and found in their Delphi study that curricular knowledge needed to be redefined and that knowledge of assessment was not valued. This ties in with what we find here, a lack of feedback and little communication, interaction (or even co-construction or co-teaching) with teachers.

6.2.2 Content

Our data showed that traditional astronomy topics (celestial motion, constellations, planets etc.) are more often presented live, and contemporary topics are typically (though much less often) presented through films. Given the planetarium was designed

for portraying the night sky and simulating celestial motion, and its history, it is perhaps not surprising that the traditional topics are the most common topics in live presentations. However, while digital projectors are not ubiquitous, they are increasingly common and allow to project anything, including detailed images and simulations from contemporary advances in astronomy.

In our sample 7% of the participants work in a planetarium with no means of digital projection on the dome (although 30% of these planetariums do have a 2D projector). This group is too small to explain the large differences between the traditional and contemporary topics. It is not the focused interest of planetarium visitors', since they have "learning interests" in both traditional topics (e.g., constellations) and contemporary topics (e.g., black holes) (Zajan and Stengler, 2021). We could hypothesise that the focus on traditional astronomy topics could be due to several interconnected reasons, which includes: the planetarians are less comfortable with more recent topics and rely on films to explain those topics; planetarians like to follow traditions; there is a larger offering of films on contemporary issues (rather than traditional topics); or planetarians are tied (or at least inspired) by the curriculum which is focused predominantly on traditional topics (Salimpour et al., 2021a). The data from the current study cannot ascertain the underlying reasons, and so it provides fertile ground for further research to explore the underlying reasons.

6.2.3 Goals of shows

Planetaria are an interesting context where there is the blurring between education and entertainment. For planetaria that are part of museums, concert halls or other settings, the value of entertainment might be higher than for planetaria that are part of a school or higher education institution where education comes first. Furthermore, most planetaria cater to both the general public and school audiences. Prior to undertaking this research, we hypothesised that planetarians would make shows for the general public more entertaining, and lessons for school audiences more educational. However, our survey results provide evidence (Table 6, Figs. 13-15) that in general irrespective of the group entertainment comes before educational goals. This does not mean that visitors cannot expect both. This is contrary to the work by Small and Plummer (2010) and Croft (2008), who concluded based on their data "that planetarium professionals are far more interested in educating their audiences than entertaining them" (p. 8).

One reason for this difference is perhaps due to how participants interpret the idea of education and entertainment, and more in-depth qualitative research is required to explore deeper nuances in these findings. However, it is possible that planetarians are more inclined to entertainment than to education. Perhaps this is due to the lack of distinction that planetarians make between the general public and school audiences. If planetarians regard them as similar, and if they think that the general public should be entertained to make sure they return, then perhaps planetarians will also invest more in entertaining over education for school audiences. Likewise, planetarians might not make a clear distinction between science education and science communication in their practice. This is not surprising as the planetarium caters to both school audiences and the general public and because the planetarium blurs the boundary between formal and informal learning. Previous research into planetarium visitors' interests (e.g., Trucks et al., 2022) has not asked, to our knowledge, whether visitors' interests are mostly educational, entertainment seeking or looking for engagement. Research has, as illustrated by the review book by Slater and Tatge (2017), focused primarily on educational aspects of planetariums (with most attention on cognitive goals, and less on attitudinal and affective goals). In other words, from a research point of view, the planetarium is an educational institution first, more so than an entertainment institution. It is therefore striking that many planetarians (the majority in our sample) indicate that they think that visitors are expecting to be entertained first (this does not exclude educational expectations).

The entanglement between education, entertainment and engagement is not a trivial one (Baram-Tsabari and Osborne, 2015). Fisher (1997) suggests that adding humour to a planetarium show resulted in decreased retention and lower test scores. In other words, more emphasis on entertainment may be paid for in reduced learning outcomes depending on how learning outcomes are "measured" and characterised.

In line with this, planetarians indicate that it is not their goal to teach the national (or regional) curriculum (Figure 13). This is surprising given that most planetarians receive school groups (Table 3), and approximately half of the planetarians interact with teachers who can indicate the content that is expected during a school visit (Figure 11). While teaching the curriculum is not their responsibility, we think that this statement was perhaps interpreted very strictly by the respondents. Given the interactions with teachers, or even without, we expect that planetarians align their presentations to the teachers' needs and educational (curricular) goals. However, their response may also be explained by the planetarians not distinguishing between school audiences and the general public.

Along the same lines, it is interesting to gain some insight into the perception planetarians have of the people visiting. While we did not ask this question directly, our data suggests that many (at least one-third) planetarians think of visitors as lacking knowledge, i.e. visitors have a deficit that needs to be filled. As planetariums bridge science education and science communication, this brings to mind the deficit-model of science communication (akin to the transmission model of education (Baram-Tsabari and Osborne, 2015). The reason for the inference is that our data shows that planetarians who we surveyed aim to increase declarative knowledge, not reasoning skills. Furthermore, one-third of the planetarians surveyed reported that they do not interact with visitors during the show, which is needed to go beyond a deficit approach to science communication and science education. Research in both science communication and education is arriving at the consensus that merely lecturing about facts to fill a deficit in the visitors' knowledge is not the way forward (Baram-Tsabari and Osborne, 2015). Rather, planetariums should work towards developing and understanding dialogue and participation models (in science communication) and (social) constructivism, active learning and various participant-centred pedagogies (in science education).

6.2.4 Difference between the general public and school audiences

Throughout our data we consistently find that planetarians do not really make a great distinction between school audiences and the general public. This is a striking result. After all, in teaching and effective communication it is well accepted that one should account for the target audience, change what you say, how you say it, which tools you use (what you show) and in what order. Is this a superficial result that disappears if one were to observe lessons/shows? Perhaps, but if this result persists, then this insight leads to a range of questions that need to be explored. Does the dark environment of the planetarium reduce interaction with the audience thus not allowing to distinguish between students and general public visitors? To what extent are planetarians aware of guiding principles in education and communication? Can the science communication in planetariums best be described using the deficit model (in science commu-

nication theory) or by (social-)constructivism from educational sciences (or another theory)? Can professional development of planetarians increase the use of different approaches between school- and general public audiences?

6.3 Professional Identity

The professional identity of the participating planetarians was investigated using different constructs which includes confidence in their own expertise, job satisfaction, and professional development.

More than 80% of planetarians indicated to have 'some expertise' in astronomy content and/or teaching and learning. We interpreted this to mean that planetarians who stated that they do not have 'some expertise', as an indicator of a lack of confidence. Equally possible is that it could be interpreted as a sign of humility.

While no correlations could be found with other independent variables, we observed that less confident participants were more likely to have teacher-centred interactions with the audience. This is not surprising. If a person is not confident, they would be inclined to follow a predetermined program, which allows more control and predictability. This is in line with literature which tells us that teachers struggle more to answer questions from students and are more rigid in their interaction when they are teaching out-of-field (i.e., the teachers do not hold a major or minor in the discipline) (Sanders et al., 1993) as cited by Nixon, Luft & Ross(2017)).

Note that confidence in one's own expertise does not imply actual expertise. After all, there is a non-linear relationship between confidence and expertise, as was hypothesised by Kruger and Dunning (1999) (though this hypothesis is questioned (Gignac and Zajenkowski, 2020)).

Interesting results emerged from asking how planetarians strive to improve their own practice, to what extent they follow the literature, advances in related (research) fields or professional development, whether they asked for feedback, and whether they actually integrate these new insights. Overall, large numbers of planetarians indicate that they follow advances in research (certainly in astronomy, but also in science education, planetarium education, informal learning or science communication). Additionally, planetarians indicated that they do incorporate new insights into their practice (certainly in astronomy, to a lesser degree in science communication, and even less in science education, planetarium education, or informal learning research). These results are in line with the findings of Plummer and Small (2013). These numbers are also large compared to formal education settings where a general low interest of teachers in research is reported (e.g., Broekkamp and Hout-Wolters, 2007; Sato and Loewen, 2019; Vanderlinde and Van Braak, 2010), despite its positive effects on the teaching practice (e.g., Cain, 2015; Judkins et al., 2014; Salter and Tett, 2022). However, our data does not tell us anything about the breadth or depth to which the planetarians engage with this literature, or the quality of their engagement or implementation of the things they learned from literature. The data also showed that many planetarians do not receive any form of regular professional development.

These results provide the justification for more, qualitative, in-depth, research to obtain a complete picture of the professional identity and professional development of planetarians.

6.4 Suggestions for future work

The aim of this work was to provide a bird's eye perspective on planetarians. However, it introduces many new questions. Some might be answerable using the rich data collected in this work. Here we will list where we see possibilities for future research, also summarizing the suggestions for future research that have been made throughout the text.

- Are the goals, presented content, type or level of interaction dependent on the planetariums' geographic location, organization, size,…?
- Are the goals, presented content, type or level of interaction dependent on the planetarians' educational background, the audience,…?
- To what extent does the educational background of planetarians influence the teaching practices and on the learning of the visitors?
- What are planetarians' pedagogical content knowledge?
- How does planetarians' PCK develop given the particularities of a planetarium pertaining to the physical and organizational characteristics but also to the characteristics of typical visits?
- What are characteristics (quantity, quality, type,…) of interactions (between visitors, between the planetarian and the visitors, maybe even between the visitors and the dome) in a planetarium?
- Verbal interaction is most common, but what other ways of interacting are possible inside a planetarium dome?
- Literature suggests pre- and postvisit work in schools, however this seems to be less common. What are barriers and possible solutions to stimulate these activities?
- Why are traditional topics more prevalent in planetarium shows than contemporary topics (or even cutting edge research)?
- Does the dark environment of the planetarium reduce interaction with the audience thus not allowing to distinguish between students and general public visitors?
- To what extent are planetarians aware of guiding principles in education and communication?
- Can the science communication in planetariums best be described using the deficit model (in science communication theory) or by (social-)constructivism from educational sciences (or another theory)?
- Can professional development of planetarians increase the use of different approaches between school- and general public audiences?
- What is the breadth and/or depth to which the planetarians engage with research literature?
- How do planetarians implement the findings from literature?
- What is needed to support the professional development of planetarians (individual or as a global community)?

7 Conclusion

Planetarians are key figures in the educational choices made in planetariums. Mapping out who the planetarians are, their background, the professional choices they make, how they interact with visitors, and their professional identity are important first steps in understanding the educational practices in planetariums. In this work, we conducted a global planetarian demographic survey to provide initial big picture insights into the above constructs.

The survey was conducted on a global level, reaching 305 planetarians, from 46 countries, speaking at least 12 languages, reaching all continents of the globe where planetariums exist.

The aim of this research and of this paper is to allow future planetarium research to compare its contexts to others and, importantly, highlight various research avenues that are worthy of pursuing within the context of planetarium education. We think an international approach is important in planetarium research. As such, it might be possible to get a representative global sample involved in research (which is much harder in traditional educational settings) and it would allow research to be conducted that goes beyond a case-study design (which, while valuable, can be limited in its implications and applicability elsewhere). Similar to the world planetarium database (WPD, 2021) this work explicitly takes this international stance. We encourage future planetarium research(ers) to compare the context, setting and background of the participating planetariums and planetarians with the global picture of planetariums and planetarians (for which we provide a start, but which will hopefully be further refined in the future).

Schultz and Slater(2020) suggested that planetarians are different from school/higher education astronomy teachers. Indeed, we also find that planetarians are a diverse group with various backgrounds, and that planetarians are initially attracted to working in a planetarium because of their interest in astronomy, science, and science communication rather than by teaching and learning. Yet, our findings also nuance this previous result. Almost all planetarians do attend to school groups, give presentations on topics that are in the curricula worldwide and conduct typical lectures with limited interaction. Moreover, planetariums offer a very particular type of education. Thus, we think the theoretical frameworks developed in science education research can be valuable to get a deeper understanding of planetarium education, planetarians as key players in this specific type of education and planetarian professionalisation. Inversely, we also think that planetarium education research may also be of interest to researchers of science education in formal (school-)settings and to researchers of science education in other, informal, out-of-school science education settings (e.g., zoos, aquaria, science centers, museums etc.).

Summarising noteworthy findings of the three main constructs investigated in this work: **Planetarian profiles (RQ1):** There are planetarians of all age groups (though mostly between 26-55), of both sexes (though mostly male), with many different educational backgrounds (though mostly physics or astronomy, and mostly on a master level). Despite their different backgrounds, almost all participating planetarians showed interest in astronomy, science, and science communication (more so than in education).

Interaction (RQ2): Despite interaction being valued in educational research and being established as key in quality education, the types and amount of interaction by planetarians with their visitors can be limited during the presentations. An important future research goal could be to explore the effects and variety of interactions possible in planetarium shows.

Professional identity (RQ3): Planetarians see themselves as professionals and most follow research, though mostly about astronomy and much less about science communication or education. This research did not investigate the quality of interaction with the research they read. Further research is necessary to, amongst other things, develop professional development programs for planetarians.

Overarching findings: Two results emerged in all three constructs: 1) planetarians seem to prioritise entertaining over educating and 2) planetarians seem to make no distinction between school audiences and the general public. These two might be related. Of course, these two general findings hide a lot of individual differences and are the result of our specific research approach. Additional research is needed to verify these findings and explore the nuances.

It should be clear that there are many open questions and a lot more (qualitative) research is needed to further deepen our understanding and help answer the questions that were raised in the discussion of this paper.

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9 Declarations

9.1 Ethical Approval

This project was approved by the Social and Societal Ethics Committee at KU Leuven university (Approval number G-2021-3277).

9.2 Consent for Publication

All authors have consented to this publication.

9.3 Competing Interests

The second author is co-editor of the journal, and as such the review process was allocated to the second editor of the journal to ensure double-blind anonymous peer-review.

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