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Fostering Celestial Curiosity: The SEAROAD Astronomy Workshop for the Professional Development of Indonesian Science Educators

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ABSTRACT

Community engagement in science is essential for building a knowledgeable and inspired society. This paper reports on the SEAROAD (Southeast Asia Regional Outreach Astronomy Development) Astronomy Workshop, a community service initiative designed to enhance science educators' understanding of astronomy and their confidence in teaching it. The two-day program in Bandung, West Java, involved 36 participants from diverse educational backgrounds. Pre-workshop assessments measured the baseline knowledge of participants on topics such as light pollution, telescope use, and celestial phenomena. At the same time, post-workshop surveys evaluated shifts in attitudes, perceived relevance, and interest in astronomy. Results revealed notable gaps in prior knowledge and demonstrated significant cognitive gains, with most participants achieving moderate to high normalized change scores. The workshop also strengthened pedagogical self-efficacy, particularly in integrating astronomy into classroom practice. This study presents one of the first systematic evaluations of an astronomy-focused teacher professional development intervention in Indonesia, implemented through a tripartite collaboration that combines local pedagogy, public science communication, and regional scientific partnerships. These findings highlight the effectiveness of short-term, hands-on, and contextually relevant professional development as a model for advancing science education and fostering sustained public interest in astronomy. Beyond its practical outcomes, this study contributes to the broader discourse on teacher professional development by offering an evidence-based framework for how collaborative, intensive, and contextually grounded astronomy training can effectively enhance both cognitive and affective domains of educators in developing countries.

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Keywords:
astronomy education; community engagement; light pollution; science communication; teacher professional development

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INTRODUCTION

Public outreach and community service are increasingly recognized as cornerstone responsibilities of the global scientific community. Beyond the confines of laboratories and academic journals, a critical mandate exists to build robust bridges that translate complex scientific concepts into accessible, meaningful knowledge for society. As Stocklmayer (2012) argues, this endeavor is not merely about remedying a "deficit" of public knowledge but about fostering a dynamic, ongoing dialogue between science and society. Recent studies emphasize that overcoming the deficit model requires relational approaches such as dialogic engagement and community-based collaboration, which prioritize mutual understanding and trust-building between scientists and the public (Choi et

al., 2023; Wang, 2025). These approaches challenge the assumption that simply transmitting scientific facts is sufficient, instead recognizing the importance of values, context, and shared meaning in science communication. This form of engaged communication is crucial for fostering a scientifically literate public that can make informed decisions on pressing global challenges, ranging from public health crises to climate change. The COVID-19 pandemic, in particular, revealed the dangers of misinformation and highlighted the importance of transparent and empathetic communication strategies, as noted by Kisa and Kisa (2024). Stylinski et al. (2018) further demonstrate that comprehensive training in public engagement can significantly enhance scientists' outreach attitudes and practices, reinforcing the value of two-way exchanges. These efforts not only improve public understanding but also strengthen scientists' sense of purpose and connection to societal needs. By engaging the public meaningfully, the scientific enterprise renews its social contract. It ensures that scientific discoveries remain relevant, accessible, and beneficial to the broader human experience.

Astronomy holds a uniquely privileged and influential position within the broad landscape of science communication. Its inherent capacity to evoke a sense of wonder and awe, as well as its connection to fundamental questions about our origins and place in the universe, makes it a potent tool for engagement across diverse cultures and age groups. For this reason, astronomy is often considered a "gateway science", an accessible and inspiring entry point for generating broader, sustained interest in the more complex STEM (Science, Technology, Engineering, and Mathematics) fields (Bilad et al., 2024; National Research Council, 2009). Recognizing this potential, major international bodies, such as the International Astronomical Union (IAU), have placed global outreach and education at the heart of their mission. The IAU's strategic plan explicitly emphasizes astronomy as a tool for education, development, and diplomacy, aiming to create inclusive and engaging opportunities for all and leveraging the field to help achieve the UN's Sustainable Development Goals (IAU, 2018).

While public outreach is vital, a more strategic and high-leverage approach to science education involves the targeted professional development of in-service teachers and educators. These individuals are the primary conduits of scientific knowledge for the next generation and act as powerful "multipliers"; empowering a single teacher with new knowledge and pedagogical skills can positively impact hundreds of students throughout their career (Supovitz & Turner, 2000). However, science educators face significant challenges, including a lack of access to up-to-date scientific information, limited resources for hands-on activities, and a need for effective pedagogical strategies that move beyond rote memorization to foster genuine scientific inquiry (Crawford, 2007). Decades of educational research have demonstrated that effective teacher professional development (TPD) is not a one-time event, but a sustained process characterized by a strong content focus, opportunities for active learning, and coherence with school curricula and goals (Garet et al., 2001). Providing teachers with these opportunities is one of the most impactful forms of community service a scientific institution can undertake.

This imperative for high-quality teacher training is particularly salient within the Indonesian context. As a nation striving to build a knowledge-based economy, Indonesia places a strong emphasis on improving its STEM education outcomes. However, challenges persist, including disparities in educational resources between urban and rural areas, as well as a need for more widespread implementation of inquiry-based science teaching methodologies. Recent assessments such as PISA 2022 have placed Indonesian students significantly below the OECD average in science literacy (OECD, 2023b), reflecting systemic issues that are partly linked to teacher preparation and the availability of effective professional development programs. Similarly, Carney (2022) reports highlight that uneven access to quality teacher training in developing countries, including Indonesia, remains a significant barrier to achieving equitable science education. Investing in the professional development of its

science educators is a national priority, and initiatives that provide localized, hands-on, and scientifically current training are essential to support this goal. Programs designed and implemented locally, like the one discussed in this paper, are crucial for ensuring that the content is scientifically accurate and culturally and pedagogically relevant to the needs of Indonesian teachers and their students.

Despite national aspirations for improved STEM competence, explicit attention to astronomy within Indonesian curricula and routine teacher training remains limited. As a result, teachers often lack both curricular resources and specialized pedagogical training to teach astronomical topics with scientific depth and classroom relevance. International reviews and policy analyses emphasize that where curricula prioritize scientific literacy but fail to specify content-area support, targeted professional development is a necessary corrective (UNESCO, 2021; OECD, 2023a). In other words, there is a clear and actionable gap between the recognized potential of astronomy as a gateway to STEM and the limited professional preparation available to teachers in Indonesia.

Prior research in science education (Crawford, 2007; Supovitz & Turner, 2000) and international models of teacher professional development (Garet et al., 2001; Darling-Hammond et al., 2017) demonstrate the effectiveness of content-focused and sustained training. Nevertheless, a clear gap exists in context-specific programs that integrate global scientific knowledge with local educational realities. Specifically, although astronomy is repeatedly invoked in international outreach agendas as a powerful engagement tool, there is a scarcity of empirical evaluations of astronomy-focused TPD in Indonesia and similar developing-country settings. This scarcity limits our understanding of what program designs work in these contexts and why. In the short term, intensive workshops, when grounded in pedagogical best practices and adapted to local needs, may provide a feasible and impactful alternative. This study seeks to address that gap.

It was to address this specific need that the SEAROAD (Southeast Asia-Regional Astronomy Outreach Development) Astronomy Workshop was conceived and implemented in Bandung, Indonesia. This community service project was founded on a unique and powerful collaborative model, bringing together three distinct but complementary organizations. The first, Laboratorium Bumi dan Antariksa of Universitas Pendidikan Indonesia (UPI), provided a strong foundation in educational theory and pedagogy, grounding the workshop in research-based teaching practices. The second, Langitselatan, a communication media and astronomy education in Indonesia, as well as a virtual world-based astronomy community, brought invaluable expertise in science communication and community engagement, ensuring the material was presented in an accessible and inspiring manner. The third partner, the National Astronomical Research Institute of Thailand (NARIT)/ITCA (International Training Centre in Astronomy), contributed cutting-edge scientific knowledge and an international perspective, connecting local educators to the broader regional and global scientific community. This tripartite collaboration represents a holistic model for community service, integrating pedagogy, public communication, and scientific research.

The primary aim of the two-day SEAROAD workshop was to enhance the capacity of science teachers and educators to teach astronomy effectively and confidently. The specific objectives were: 1) To deepen the educators' content knowledge in key astronomical topics, including light waves, light pollution, telescope use, and the connection between astronomy and the SDGs; 2) To equip them with practical, low-cost, hands-on activities and digital tools (like Stellarium) that could be directly implemented in their classrooms; and 3) To improve their attitudes towards and self-efficacy in teaching astronomy. By focusing on socio-scientific issues such as light pollution and the SDGs, the workshop aimed to empower teachers to frame astronomy not as an isolated subject, but as one deeply connected to environmental stewardship and sustainable development —a key goal of modern science education (Zeidler et al., 2005).

This paper provides a comprehensive account and critical evaluation of the SEAROAD workshop, positioning it as a model of community service–based professional development for science educators. In doing so, it aims to enrich the growing body of literature on the practical assessment of science outreach initiatives (IAU, 2018). Specifically, the study addresses three guiding research questions: 1) To what extent did the workshop enhance educators' content knowledge in selected areas of astronomy?; 2) In what ways did the program shape their attitudes and dispositions toward teaching astronomy?; 3) Which elements of the workshop, including the content focus, pedagogical strategies, and collaborative design, were perceived as most valuable for their professional practice? To answer these questions, the following sections will detail the methodology used to collect and analyze data from the 36 participants, present the quantitative and qualitative findings in a combined results and discussion section, and conclude with the implications of this project for future community service initiatives in science education.

METHOD

To understand how the SEAROAD workshop fulfilled its purpose, it was important to design an evaluation that went beyond numbers and statistics. The methodology was therefore guided by the intention to capture not only measurable improvements in knowledge but also the lived experiences and reflections of the participants as educators. In line with the literature on teacher professional development, effective evaluation requires attention to both content-specific learning outcomes and pedagogical growth (Desimone & Garet, 2015; Garet et al., 2001). At the same time, the use of a mixed-methods framework provided a means to integrate quantitative measures with qualitative insights, yielding a more holistic understanding of the intervention's impact (Creswell & Clark, 2017). By combining these perspectives, the study aimed to provide a balanced and meaningful account of the workshop's outcomes, offering insights that are both rigorous and relevant to future professional development initiatives. To contextualize the workshop outcomes, Table 1 summarizes the participant profile for the SEAROAD (N = 36). The table presents three key demographic categories: city, profession, and school/institution origin. This information enables readers to appreciate the professional and contextual diversity of the sample and to interpret the results with appropriate nuance.

Table 1. Participant Profile for the SEAROAD Workshop (N = 36)

Variable	Category	n	%
City of Origin	Bandung	24	67
	Other Cities	12	33
Professional Role	School Teacher	24	67
	Student (undergraduate/graduate)	8	22
	Science Communicator	4	11

The SEAROAD (Southeast Asia Regional Astronomy Outreach Development) Astronomy Workshop was conceived as a high-impact, full-day professional development program for science educators. The event was held on May 1617, 2025, in Bandung, Indonesia. Its design was underpinned by a unique collaborative model uniting three key institutions: the Laboratorium Bumi dan Antariksa of Universitas Pendidikan Indonesia (UPI), which provided pedagogical expertise; the public science communication organization Langitselatan, which brought community engagement strategies; and the National Astronomical Research Institute of Thailand (NARIT), which contributed international scientific authority. The curriculum was carefully structured, including expert lectures and interactive,

hands-on activities. This community service project was evaluated using a mixed-methods approach, which was chosen to provide a comprehensive understanding of the program's impact. The combination of quantitative and qualitative techniques enabled the capture of both measurable learning outcomes and deeper insights into participants' experiences. The mixed-methods design was considered particularly suitable for professional development research, as it allows the assessment of knowledge gains alongside changes in attitudes and teaching confidence.

The methodological design was closely aligned with the study's objectives. Specifically, the evaluation aimed to examine three main aspects: first, the extent to which the workshop improved educators' content knowledge in astronomy; second, the influence of the workshop on participants' attitudes toward teaching astronomy; and third, the aspects of the program that participants perceived as most relevant and valuable for their professional practice. By structuring the evaluation around these objectives, the study sought to provide both accountability for the intervention and evidence of its potential as a model for similar community service–based teacher training initiatives.

To evaluate the outcomes of the SEAROAD workshop, a four-part questionnaire was administered to all 36 participants. Section A gathered demographic and professional background data. Section B assessed content knowledge through 20 multiple-choice questions covering fundamental astronomy concepts (light waves, power of tens), observational skills (moon phases, telescope use, planet walk), modern tools (Stellarium software; https://stellarium.org/), and socio-scientific issues (light pollution and the links between astronomy and the Sustainable Development Goals). Section C explored participants' attitudes toward astronomy with six Likert-scale items that measured interest, confidence, and perceptions of astronomy's educational and societal value. Section D collected feedback on the workshop through seven items, combining Likert-scale ratings with open-ended questions, which focused on time allocation, materials, activities, and facilities. Together, these four sections provided a systematic account of participants' demographic context, knowledge gains, attitudinal shifts, and overall perceptions of the workshop.

The collected data were analyzed using a mixed-methods framework. For the quantitative components, knowledge gains from Section B were calculated using normalized change (N-change) scores, following the formula proposed by Marx and Cummings (2007). Attitudinal changes captured in Section C were examined through descriptive statistics, including means and standard deviations, and further tested using paired-samples t-tests to determine statistical significance. Data from Section D were summarized descriptively to reflect overall participant satisfaction. In parallel, the open-ended responses were analyzed thematically. This process involved carefully reading, coding, and categorizing participant comments to identify recurring themes, highlight key suggestions, and include illustrative quotes that could contextualize and deepen the quantitative results. Together, these complementary approaches ensured a rigorous and holistic evaluation of the workshop.

RESULTS AND DISCUSSION

This Section presents and interprets the findings from the SEAROAD workshop evaluation in line with the three guiding research questions. It begins by examining the participants' baseline knowledge and subsequent learning gains, followed by a topic-specific analysis of conceptual growth. The discussion then turns to the affective outcomes, particularly shifts in teachers' attitudes and self-efficacy, before exploring participants' feedback on the relevance of the workshop. Finally, the broader implications of the findings are synthesized to highlight the study's novelty, impact, and contributions to science education and outreach. A primary objective of the workshop was to enhance educators' knowledge of astronomy content. Pre-test results revealed a relatively strong foundation, with a mean score of 16.44 out of 20, but also substantial variation across participants (SD = 3.26). This diversity underscored the need for differentiated professional development opportunities. Post-test results

demonstrated a statistically significant improvement, with the mean score rising to 18.64, an average gain of 2.2 points.

To provide a more rigorous measure of individual progress, normalized change (N-change) was calculated (Marx & Cummings, 2007). Results showed that 77.78% of participants achieved positive learning gains, with the majority in the "Moderate" (50.00%) and "High" (25.00%) categories. The distribution of participants across N-Change categories is presented in Figure 1, providing a visual complement to the descriptive statistics. Importantly, this robust pattern aligns with classic principles of effective Teacher Professional Development (TPD) that stress the importance of content-focused and active learning (Garet et al., 2001; Desimone & Garet, 2015). At the same time, it resonates with recent syntheses demonstrating that short, intensive programs can yield substantial learning outcomes when designed with coherence and practical application in mind (Blömeke et al., 2022).

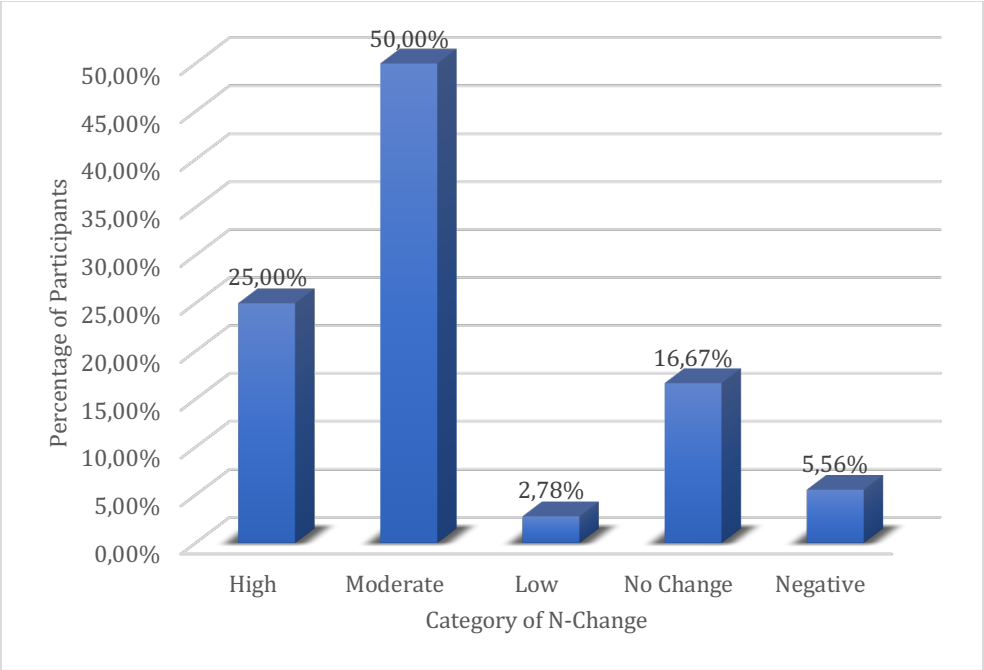

Figure 1. Distribution of Participants by Normalized Change (N-Change) Category

A topic-level analysis of normalized change values revealed nuanced learning patterns. For Light Pollution (<c> = 0.76), Power of Tens (<c> = 0.90), and Stellarium (<c> = 0.75), the workshop effectively transitioned participants from proficiency to mastery, demonstrating the capacity of focused interventions to enhance existing expertise. This supports long-standing evidence that TPD is most effective when tightly aligned with content areas (Supovitz & Turner, 2000; Desimone & Garet, 2015). The detailed distribution of normalized change values by topic is summarized in Table 2, which illustrates the variation in learning gains across conceptual domains.

Conversely, in areas such as Light Waves (<c> = 0.57), Moon Phases (<c> = 0.65), and Planet Walk (<c> = 0.65), participants achieved substantial conceptual growth. The result for lunar phases is particularly noteworthy, given the persistence of misconceptions in astronomy education research (Slater et al., 2010). Achieving moderate-to-high gains in such challenging areas highlights the workshop's capacity to facilitate conceptual change (Posner et al., 1982), an achievement consistent with more recent findings on embodied cognition and its value for teaching abstract scientific ideas (Cole et al., 2018; Goldin-Meadow & Beilock, 2010).

Table 2. Normalized Change (N-Change) Analysis by Topic

Topic	Max Score	Pre-Avg	Post-Avg	Avg. ⟨*c*⟩	Change Category
Light Wave	2	1.36	1.72	0.57	Moderate
Light Pollution	3	2.31	2.83	0.76	High
Power of Tens	2	1.72	1.92	0.90	High
Telescope	2	1.83	1.88	0.33	Moderate
Moon Phase	2	1.36	1.77	0.65	Moderate
Plane Walk	2	1.44	1.81	0.65	Moderate
Stellarium	2	1.88	1.97	0.75	High
SDGs	5	4.53	4.67	0.29	Low

The affective outcomes were equally important. Although participants initially showed a generally high appreciation for astronomy, the workshop catalyzed significant improvements in their pedagogical confidence. The most notable shift occurred in self-efficacy: pre-test averages for teaching confidence rose from 4.14 to 4.66, with a normalized change of <c> = 0.61. These results are summarized in Table 3, which highlights the magnitude of change across different attitudinal items. This result echoes foundational theories of self-efficacy as a mediator between teacher beliefs and classroom practice (Bandura & Walters, 1977; Tschannen-Moran & Hoy, 2001), while also aligning with contemporary research emphasizing the role of confidence in ensuring the transfer of professional learning into instruction (Holzberger et al., 2013; Gess-Newsome et al., 2019; König et al., 2021). These findings are significant because they enable teachers to move beyond merely valuing astronomy to feeling capable of teaching it effectively. This transition from recognition to action reflects the well-documented intention–behavior gap (Ajzen, 1991) and highlights how carefully designed professional development can bridge it (Kennedy, 2016; Sancar et al., 2021). In this way, the workshop bridged the intention–behavior gap, positioning teachers to enact sustainable classroom change.

Table 2. Summary Statistics of Section C (Attitude Towards Astronomy)

Item	Pre-Avg	STDPre	Post-Avg	STDPost	Avg. ⟨*c*⟩
Item 1	4.78	0.48	4.78	0.76	0.00
Item 2	4.58	0.81	4.86	0.42	0.67
Item 3	4.72	0.51	4.92	0.28	0.70
Item 4	4.61	0.60	4.75	0.73	0.36
Item 5	4.14	0.76	4.67	0.48	0.61
Item 6	4.56	0.56	4.70	0.47	0.31

Participants' qualitative feedback underscored the perceived relevance and transferability of the workshop. Hands-on activities, accessible digital tools, and connections to real-world issues such as light pollution were consistently praised. Nearly all participants rated the workshop content as "Very Good" (94.4%), with comments highlighting applicability to classroom practice. While a minority suggested extending the time allocation, this feedback reflects the richness of the content rather than dissatisfaction with it.

Such participant engagement illustrates not only satisfaction but also perceived value—a vital dimension of the impact of professional development (Timperley, 2011). The combination of pedagogical accessibility, scientific rigor, and contextual relevance is what distinguishes the SEAROAD workshop as both effective and novel in the regional landscape. By situating astronomy within broader socio-scientific contexts, the workshop also responded to the need for education that integrates science learning with societal issues (Zeidler et al., 2005). Ultimately, the initiative extends

beyond short-term outcomes by fostering a sustainable culture of astronomy education in Indonesia, where teachers and students alike can continue to discover relevance, curiosity, and empowerment in exploring the universe together.

While the immediate outcomes of the SEAROAD workshop are promising, its long-term significance lies in its potential for sustainability and scalability. The collaborative model, which integrates pedagogical expertise, community-based science communication, and international scientific perspectives, can be replicated in other regions of Indonesia and Southeast Asia by adapting the content to local curricular needs and cultural contexts. Ensuring knowledge transfer from teachers to students requires embedding the workshop's tools and approaches into classroom practice through follow-up mentoring, peer-learning networks, and access to digital resources that extend beyond the event itself. This process not only consolidates teachers' gains but also amplifies their reach to hundreds of students in diverse educational settings. At a policy level, the workshop aligns with Indonesia's national priority of strengthening STEM education. It aligns with international recommendations, such as UNESCO's call for transformative teacher professional development to advance sustainable development (UNESCO, 2021), and the OECD's emphasis on teacher quality as a key driver of student achievement (OECD, 2023a). By demonstrating measurable cognitive and affective gains, the SEAROAD model provides evidence-based insights that can inform national education strategies and encourage investment in contextually grounded, high-impact professional development programs. In this way, the initiative contributes not only to the immediate participants but also to the broader goal of advancing science education and fostering sustainable public engagement with astronomy.

CONCLUSION

The SEAROAD Astronomy Workshop demonstrated that short-term, high-intensity professional development can generate measurable and meaningful outcomes for science educators by strengthening both their content knowledge and pedagogical self-efficacy. Quantitative analyses revealed significant learning gains across diverse astronomical topics, with most participants achieving moderate to high normalized change scores. Affective measures indicated a substantial increase in teachers' confidence in integrating astronomy into classroom practice. This impact was amplified by a collaborative model that combined pedagogical expertise, science communication, and international perspectives, ensuring that the program was rigorous, contextually relevant, and culturally accessible. By embedding astronomy within broader socio-scientific contexts such as light pollution and the Sustainable Development Goals, the workshop not only deepened disciplinary understanding but also empowered teachers to frame astronomy as a vehicle for critical thinking, environmental stewardship, and global citizenship. Theoretically, this study contributes to the literature on teacher professional development by illustrating how short, intensive interventions, when grounded in contextual and collaborative design, can effectively bridge the intention–behavior gap in science education. At the policy level, the findings provide evidence that targeted and context-sensitive teacher training can complement national STEM priorities, support equitable access to quality education, and inform strategies recommended by UNESCO and OECD for raising science literacy in developing contexts.

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