In Support of Astronomy Education Research

Submitted to the Subcommittee on the Status of the Profession
Education and Public Outreach (EPO) Infrastructure Study Group.
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1. Introduction

Astronomy education research is that area of inquiry at the interface of modern astrophysics, education, psychology and the cognitive sciences. Although there have always been individual astronomers, who sought and developed effective techniques for teaching, engaging in that activity that we now call astronomy education research, it is only in the last decade or so that we have seen the emergence of a scholarly field. Today, there are graduate programs, doctorates are awarded, competitive funding programs and a peer reviewed, online journal devoted to astronomy education research, Astronomy Education Review.

It is about as silly to ask what is astronomy education research's value to the astronomical community as it is to ask what is the value of, for example, exoplanet research, or of building ever larger diameter telescopes. Modern astrophysics benefits from all of these, resulting in new knowledge, better understanding and leading to advancement of the field. AER's contribution is in the development of the human capital that will lead scientific research, teach, and support astrophysics in the next decade and beyond.

2. A Very Brief History of Astronomy Education Research

Motivated by their desire to improve the quality of their own teaching and their students' understanding and appreciation of astronomy, there have always been individual scientists who focused their attention on the subject of education research. Arnold B. Arons at the University of Washington, a physicist and master teacher, undoubtedly influenced the pioneers in astronomy education, Phil Sadler at Harvard University and Michael Zeilik at the University of New Mexico, and other faculty. These individuals laid the foundations of astronomy education research, but worked alone and generally outside of the established astronomy research community.

During the last two decades, NASA's Science Mission Directorate (then the Office of Space Science) and the NSF directed Principal Investigators to include EPO (Education and Public Outreach) activities as part of their proposals increasing awareness, and effort, in the arena of astronomy education. But inadvertently causing confusion as to what the difference is between EPO and education research.

Astronomy education research (AER) is not about how to deliver classroom lectures with enthusiasm, nor is it about providing memorable public talks on the wonders of astrophysics, nor showing gorgeous images of astrophysical objects, nor encouraging scientists to visit schools nor even writing beautiful textbooks. At its core, astronomy education research is about rigorously investigating and understanding how people learn astrophysical concepts, and how to develop and deliver resources that help students learn, and, teachers teach. [See the Astronomy Education Research Charter, included in Appendix A]

It is worth noting that during this same time period, math and science educators were deeply embroiled in the development of math and science standards for elementary, middle and high

school classes, which activity resulted in the publication of Benchmarks for Science Literacy (1993, AAAS) [1] and the National Science Education Standards (1996, NAS) [2]. Influenced by these efforts, the American Astronomical Society funded workshops for astronomy departments chairs, the results of which were published as Goals for "Astro 101": Report on Workshops for Department Leaders in 2003 [3]. At the same time, the NSF's Education and Human Resources Division provided increased funding for science education research. Physics education research (PER) benefited tremendously. The professional societies, APS, AAPT and in a second grant, with the AAS, developed the Physics and Astronomy New Faculty Workshop to provide college and university faculty with the tools, developed by education research, to be effective instructors [4].

At the end of the 20th century, we can safely state that the primary focus of education research was on how to teach introductory astronomy better, and the primary audience (or consumer) was undergraduate faculty.

3. Astronomy Education Research In the 21st Century

Today, at the start of the 21st century, the landscape of astronomy education research has changed tremendously. The field has grown significantly, from handfuls of individuals to approximately one to two hundred, as evidenced by the increase in the number of sessions and abstracts at the semi-annual meeting of the American Astronomical Society, and the increase in the number of peer-reviewed publications. This growth is reflected in and/or reflects the following changes:

- Some astronomy departments now have tenure-track, faculty appointments, e.g. University of Arizona, many more have research scientist, post-doctoral and adjunct positions in their Physics and Astronomy departments, e.g. University of Maryland, Southern Illinois University, and several now also offer graduate degrees in AER, e.g. University of Arizona, Boston University.
- A peer-reviewed, electronic journal, the Astronomy Education Review, now publishes scholarly articles [5].
- The audience or consumers of AER has changed, and,
- The American Astronomical Society recently added a new category of member – the education affiliate, in recognition of the growth in astronomy education and research.

Since the first and second bulleted items are likely addressed in other papers submitted to this committee, it will not be further discussed here. Instead, this section will focus on the third item, in part because it will help to identify future directions within AER.

Three primary audiences are now identified for astronomy education research. These are:

1) Professionals who want to assess the knowledge and skills of astronomy students.

This assessment dimension is important for teachers, instructors and faculty, curriculum developers, and EPO evaluators. This group needs assessment tools, which astronomy education research should provide to help direct what happens in the classroom. Resources should be spent on the creation and validation of concept inventories that assess the level of knowledge and understanding student's hold when they first enter the classroom or lecture hall. Existing concept inventories include the Lunar Phases Concept Inventory (LPCI) [6], Light and Spectroscopy

Concept Inventory (LSCI) [7], [8] Star Properties Concept Inventory (SPCI) [9] and the Greenhouse Effect Concept Inventory (GHCI) [10]. Additional resources should be spent on efficacy or diagnostic tests, which measure the effectiveness or gain in learning. The oldest of these is the Astronomy Diagnostic Test (ADT) [11], dating from 1999. The newer Test Of Astronomy STandards (TOAST) Assessment Instrument [12], [13] is aligned with the Astro 101 goals, and has been presented at the recent AAS meeting, and in 2008 at a meeting of the AGU, but has not yet been published.

Clearly, there is a need for additional inventories, as these encompass only a few of the concepts typically taught in an introductory course. Considerable effort is still needed to add to and expand upon these instruments if they are to be adopted by instructors. However, these concept inventories and diagnostic tests are designed to be administered as a whole, and May not always coincide with instructors' syllabus structures. So in addition, as a community we need to know if these tests are robust in electronic form, and can be made available in a module form where instructors could access question-sets based on the concepts they want to test.

2) Elementary and Secondary School Administrators and Educators.

The national science education standards and diploma movements require the astronomy community remain vigilant, for three principal reasons. First and foremost, to ensure that K-12 science teachers are adequately prepared to teach astronomy and space science (as called for in the majority of state science education standards). Second, is to ensure that textbook content is accurate and appropriate, and, that associated activities, e.g. homework and laboratory exercises, are research-based and validated. The same is true for interdisciplinary materials in mathematics and reading. AER's specific role is to provide the data supporting the inclusion of Space Science and Astronomy in the K-12 curriculum. Resources should be directed in this area early, anticipating the need of policy makers in the national and state departments of education for such evidence. Lastly, research in K-12 science education is needed to effectively increase science literacy, and, perhaps more importantly, ensure that real science is taught and not hijacked by anti-science individuals and organizations.

Progress is being made in how best to prepare pre-service teachers, and, to provide professional development for in-service teachers, as in these articles by Kavanagh and Sneider [14], [15]. In the arena of textbook and curriculum publication, research-based materials are less evident. Science literacy does not seem to have been affected by astronomy education research, clearly more work is required in this area.

3) Research Scientists who Work at the Interface Between Astronomy And Learning.

This audience forms the scholarly vanguard, whose members **are** the researchers in astronomy education. These are the people who engage directly with the interesting questions at the interface between astronomy as a science discipline and learning. We know today that understanding how people learn [16] astronomy encompasses much more than the old ideologies of misconceptions, preconception and skills transfer, [17], [18], [19], [20]. We need to instead, focus on the broader concept of resources, and therefore explore what resources - prior knowledge, attitudes, and cultural influences - our students bring to astronomy. The interface of astronomy and learning is truly multidisciplinary, incorporating psychology, sociology, cognition, as well as physics, astrophysics and statistics. Reports of the last several years, including Rising above the Gathering Storm [21] and the America Competitiveness Initiative [22], and speeches by Barack Obama, newly elected president of the US, all address the need for

strengthening and improving Science, Technology, Engineering and Mathematics (STEM) education as well as by broadening participation in STEM fields. How we get there, and how quickly, depends on the resources the astronomical community brings to bear to address some of issues: How can we design curricula to access what students know and model how to use those in an useful manner.

4. The Future

Research in astronomy education to date has overwhelmingly focused on non-science major students in "Astro 101", and somewhat less on K-12 teachers and public outreach. In the decade to come we should expand upon what we have already learned and move towards understanding

1) How upper division undergraduates majors learn astrophysics,
2) How astrophysics graduate students learn,
3) How to further improve faculty teaching, for example see [23]

and,

4) How can we broaden participation in astronomy and astrophysics at all levels?

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4 New Faculty Workshop, AAPT

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7 Development and Validation of the Light and Spectroscopy Concept Inventory by Erin Bardar, Boston University and TERC, Edward Prather, University of Arizona, Kenneth Brecher, Boston University, and Timothy Slater, University of Arizona. AER, Issue 2, Volume 5:103-113, 2007.

The LSCI is a 30 item multiple-choice test (28 content items; 2 demographic items) that covers the electromagnetic spectrum, Wien's, Kirchhoff's and Stefan-Boltzmann's Laws, and Doppler shift.

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Appendix A: Astronomy Education Research Charter

Abstract: The Astronomy Education Research Charter is a statement from members of the astronomy education research community. It was originally discussed at the 2007 Astronomy Education Research Symposium. A report of the symposium and a call for public participation in its creation was published in this journal (Price et al. 2008). Participants of the symposium and members of the general public edited this document via an anonymous wiki from January 2008 to September 2008. We consider this an ongoing process and this is just the first version of this document, which is owned by the community.

Suggested Keywords:

1. Arena: Education Research (new category)
2. Broad Topic in Astronomy: Other
3. Educational Topic: Assessment, Research into teaching/learning

The Astronomy Education Research Charter

1. PREAMBLE

This charter seeks to promote excellence in astronomy education based on research-proven insights into how students learn best. To that end, we seek to guide ongoing astronomy education research, and to spread the results of that research widely throughout the community of those who teach astronomy.

2. INTRODUCTION

As a gateway science, astronomy provides key entry points for increasing scientific awareness, understanding, and appreciation among the general public. Its multidisciplinary nature offers a unique opportunity for teaching concepts that cross-traditional curriculum boundaries. Among educators, astronomy provides an appealing context for introducing scientific topics and methods of scientific inquiry. Within the field of astronomy, effective education ensures essential links between current and future practitioners of scientific research. Robust educational programs also help to justify public support of astronomical research.

The findings of astronomy education research have informed the teaching of fundamental concepts at elementary and secondary school levels. From Earth's shape and gravity, to the phases of the Moon and seasons of the year, astronomy education research has shown when and how to engage students in genuine inquiry that leads to verifiable results.

At the collegiate level, a significant fraction of the effort expended by astronomy departments, and a larger fraction of their financial support, is involved in introductory astronomy education. It behooves astronomers to approach this mission with thought because "Astro 101" may be a student's only exposure to science at this level. As education research has shown, teaching by lecture is not the most effective nor efficient method by which to promote learning. We need to engage students in more meaningful ways and provide them with the best practices of the classroom.

Astronomy education research provides crucial perspectives on learning modalities and instructional methodologies in formal and informal settings. Astronomers cannot be expected to be both producers of scientific research and creators of best education practices. A new role is being defined in astronomy departments and public outreach outlets, such as planetariums and

museums; this role is that of the astronomy education researcher. As students and the general public have increasing pressures put upon both their attention and their ways of acquiring information, progressive investment of time and resources in astronomy education research is needed.

3. RECOMMENDATIONS

3.1 For Astronomers

- Support funding for astronomy education research, and its implementation, within your organizations.
- Collaborate with astronomy education researchers and astronomy educators on research projects.
- Support the addition of astronomy education research as a component of the NRC Decadal Report.

3.2 For Astronomy Educators

- Keep up-to-date on the latest in astronomy education research and apply it to your instruction.
- Share best practices with colleagues through astronomy education research publications and presentations.
- Collaborate with astronomy education researchers on research projects.
- Be a resource to your astronomy colleagues regarding new findings in astronomy education research.

3.3 For Astronomy Education Researchers

- Publish results in peer-reviewed journals and present them at both astronomical and educational venues.
- Submit paper citations to the Searchable Annotated Bibliography of Education Research (SABER) database
- Use the research methodology (qualitative, quantitative, or both) that provides the right balance of depth and breadth of data to answer your research question.
- Use appropriate sample populations that are culturally and demographically representative of the target audience for the research.
- Follow ethical and legal guidelines when working with human subjects.
- Be rigorous concerning validity and reliability — Anecdotal and self reported measures should be used only as starting points leading to more rigorous research methodology
- Be strategic in your areas of research (e.g. More research is needed in the fields of informal education and professional development, as well as learning studies on how best to teach high school students about the structure and evolution of stars, galaxies, and the universe)
- Be familiar with the research literature inside and outside AER that underpins your study and provide adequate citations to that literature – try not to reinvent the wheel.

- Increase the use of longitudinal studies.
- Report null results of well-designed studies.

3.4 For Museums and Public Outreach Organzations

- Ensure that programs and exhibits are subject to formative and summative assessment.
- Reward E/PO specialists for participation in education research venues, such as presentations at astronomy education meetings and publications in journals.

3.5 For Professional Societies and Funding Agencies

- Recognize research activity by astronomy education researchers as professional activity that has the same merit and contribution as astrophysics research.
- Encourage and/or provide resources for astronomy education research.
- Continue supporting publication of the Astronomy Education Review.
- Incorporate keynote speakers on astronomy education research as part of departmental colloquium series, society conferences, and funding agency retreats.

4.0 REFERENCES

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