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An Analysis of Papers on Astronomy Education in Proceedings of IAU Meetings from 1988 to 2006

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Abstract

The authors analyzed 283 papers dealing with astronomy education published in the IAU proceedings from 1988 to 2006. The analysis was conducted to determine both the characteristics and trends of published research studies in order to determine whether researchers should consider taking new directions. The authors conclude that educational research requires deeper treatments dealing with epistemological questions, as well as teaching and learning processes. The authors hope that this analysis will stimulate the development of scientific investigations more appropriate to the needs of astronomy education.

1. INTRODUCTION

The IAU, the largest international organization of professional astronomers, has dedicated certain efforts to promote astronomy education in schools and for the general public under Commission 46 (Astronomy Education and Development). In the last 20 years, many papers have been presented at colloquia and special sections of General Assemblies (GA). Using this context, the authors studied the complete papers on astronomy education published in the IAU proceedings aiming at unraveling their characteristics and trends.

We focused our analysis on the following documents:

(a) The Teaching of Astronomy, IAU Colloquium 105, held in 1988 (Pasachoff and Percy 1990);
(b) New Trends in Astronomy Teaching, IAU Colloquium 162, held in 1996 (Gouguenheim, McNally, and Percy 1998);
(c) Astronomy for Developing countries, XXIV GA, held in 2000 (Batten 2001);
(d) Teaching and Learning Astronomy, XXV GA, held in 2003 (Pasachoff and Percy 2005);
(e) Astronomy for the developing world, XXVI GA, held in 2006 (Hearnshaw and Martinez 2007);
(f) Innovations in Astronomy Education, XXVI GA, held in 2006 (Pasachoff, Ros, and Pasachoff 2008).

A total of 322 complete papers were published for these events, excepting abstracts, and 283 papers (87.9%) that deal specifically with astronomy education were selected and analyzed.

2. RESEARCH ON THE STATE OF THE ART

Survey studies, description, and analysis of the academic production in any field, commonly named "state-of-the-art research," increase the knowledge of production, identify the main trends and results, highlight the advantages and shortcomings, expand the dissemination of this knowledge, suggest new possibilities of investigations, and encourage advances in this area.

In the last decades, researchers conducted studies related to scientific production in some fields of knowledge. In the field of Science Education in Brazil, we can cite the works of Megid Neto (1990), Fracalanza (1993), Megid Neto (1999), Lemgruber (2000), and Ferreira and Moreira (2001), among many others.

In the field of astronomy education in Brazil, we found two state-of-the-art works. One is the study by Bretones and Megid Neto (2005) that describes the Brazilian production of theses and dissertations addressing the teaching of astronomy up to 2002. The authors found 16 works, the first being presented in 1973. The production was categorized by different qualifiers, such as year of defense, institution, school level, the focus of the study, and method of research.

This work stimulated a second study (Bretones, Megid Neto, and Canalle 2006), this time including the works devoted to astronomy teaching presented at the most important event in Brazilian professional astronomy: *The Annual Meeting of the Brazilian Astronomical Society*—SAB. One hundred thirty seven articles presented at these meetings were studied based upon: year of publication, institution, grade level, the focus of the study, and the method of research. The study points to an increasing interest in the field with an emphasis on the elementary and middle school, in which broad astronomical contents are taught, and where conceptual problems and the absence of didactic resources are more frequently observed.

In the international literature, we found other "state-of-the-art" works in the field of astronomy education. We should mention the studies of Wall (1973), Bishop (1977), Bailey and Slater (2004a,b), and Broadfoot and Ginns (2005).

One of the earliest reports on astronomy education was written by Charles Wall (1973). The purpose of the article was to review the research studies related to astronomy education at all educational levels and to make recommendations for continued research in this area. Wall reviewed research related to astronomy education for the period of 1922–1972. In his report, he identified a total of 58 studies, 54 of which were doctoral or master's studies. The studies were conducted at the elementary school level (21), secondary school level (19), and college level (18). The studies were further classified into status articles that describe the condition of astronomy education (12 studies across the three grade categories), achievement (31), or curriculum development (15). Among the recommendations made by Wall are the effectiveness of audiovisual materials, laboratory equipment, and individualized instruction strategies, but he does not recommend studies to probe students understanding in astronomy content areas.

Bishop (1977) provided an overview of the field, including curriculum development, changing classroom demographics over time and the "state of astronomy knowledge," related to the attitudes and prevalent ideas held by the public. The highest priority and most recommended by Bishop is the need for more and better curriculum materials and teacher workshops.

Broadfoot and Ginns (2005) presented a review of research conducted in Australasia on students' concept development in astronomy. They also reported on the impact and effectiveness of some teaching and learning strategies that have been developed and employed in a variety of learning environments to address some of learning difficulties. The authors concluded by suggesting that there needs to be a greater research focus on strategies to ensure that students can scaffold and challenge their own learning of abstract and spatial ideas that are fundamental to their understanding of astronomy.

Bailey and Slater (2004a) mentioned a review of the literature in the area with articles classified into four major categories: research on student understanding, research on instructional methods, research on teacher understanding, and descriptions of curriculum materials.

Bailey, Prather, and Slater (2004) made a systematic review and classification of the literature. Some of the research themes that emerged include student beliefs and misconceptions, collaborative learning, and the Astronomy Diagnostic Test.

Another paper of Bailey and Slater (2004b) categorizes and summarizes the literature in astronomy education research. According to the authors, research on student understanding on a variety of topics now occupies a large part of the literature. Topics include the shape of the Earth and gravity, lunar phases, seasons, astrobiology, and cosmology. The authors also describe the effectiveness of instructional methods. According to them, the connection between research performed and its effect on classroom instruction is largely lacking.

More recently, Slater (2008) summarized the work reported in Ph.D. dissertations; he calls the community's attention to a new round of research results and suggests some directions for future investigation. The author considers that these Ph.D. candidates have been studying the impact of instructional innovations on student learning and systematically validating astronomy learning assessment instruments. Thus, Slater concludes that astronomy education research is maturing into a substantial disciplinary research field with many rich questions to pursue in the future.

3. METHODOLOGY

Our research is aimed at unraveling the characteristics and tendencies of the works related to astronomy education of each IAU proceeding. (Abstracts or poster reviews were not considered.) The main goals of this study were to identify, classify, and analyze these works for the purpose of identifying the main trends and making recommendations about future investigations. The works were selected from the documents published by the IAU as shown in Table 1.

Initially, we made an exploratory reading to identify common features among the various works in order to establish categories that describe the main subjects of the studies. After establishing these categories, we performed a complete reading of all the selected works, while they were being classified according to those previously established categories.

We have selected the following categories to classify these papers: the country of origin of the work, the school level or public outreach, the topics of astronomy, the focus of the study, the type of academic research, and the theoretical framework. Each work was classified according to these aspects. The data were organized into frequency tables and cross-checked to identify publication trends.

4. RESULTS

With regard to the country of origin of the paper, Table 2 shows that researchers from the United States represents 35.6% of the total of papers, followed by the United Kingdom (9.9%), India (4.9%), France (4.6%), and Canada (4.2%), among the main countries. We must point out that in the case of works with two or more authors, and when these were from different countries, the same work was classified in more than one country.

Though more than one third of the works presented on IAU events had North American authors, the distribution included 53 other countries—with an average low incidence in great majority of cases—and suggests that the concerns with astronomy education are well distributed among western and eastern countries and that the meetings and colloquia had met their goal of reaching a major fraction of the countries.

With respect to the school grade level or public outreach addressed in the papers, Table 3 shows the results of the classifications.

The greatest percentage of works were related to university education (37.8%) and to public outreach (27.6%). This is explained by the fact that astronomy is not a specific discipline in the curriculum of basic education in the majority of the countries. We may also consider the fact that it is more difficult to work with minors due to research protocol requirements of student assent and parental consent in some countries.

Table 1. Distribution of the astronomy education papers presented at IAU meetings.

Proceedings of IAU	Total of papers	Papers on education
The Teaching of Astronomy	92	91
New Trends in Astronomy Teaching	69	67
Astronomy for Developing Countries	39	19
Teaching and Learning Astronomy	21	21
Astronomy for the Developing World	56	40
Innovations in Astronomy Education	45	45
Total	322	283

Table 2. Distribution of the astronomy education papers presented at IAU meetings, by country of origin of the authors.

Country	n	%
USA	90	35.6
UK	28	9.9
India	14	4.9
France	13	4.6
Canada	12	4.2
Germany	10	3.5
Japan	10	3.5
Mexico	9	3.2
Australia	9	3.2
South Africa	5	1.8
Spain	5	1.8
Other countries	78	27.6

Even so, there is a significant number of papers on precollege education: elementary (7.8%), middle school (10.6%), and high school (12.0%). 33.9% of works dealing with a general approach, in which the author(s) did not mention for which grade level or age range the information was appropriate, are designated here as "unspecified."

We noted that the works presented at IAU meetings and colloquia related to astronomy education were mainly related to the studies on university education and to public outreach education, hampering somewhat the discussion of how to improve the teaching of astronomical concepts starting at the elementary levels. The latter approach would take advantage of the elevated potential of development and the formation of the individuals (teachers) found in the formal school systems.

In this way, we verified the existence of three groups, and a kind of balance between them in terms of percentage: university education (37.8%), precollege education (30.4%), and public outreach (27.6%). This may be explained by the fact that the majority of the authors are researchers and professors at universities in noneducation areas.

Related to the focus of the study of the works, Table 4 shows our results.

We observe that there is a predominance of papers on nonschool-program papers (28.3%). These papers show that astronomy popularization programs for the general public, and exhibitions, are being made by astronomical institutions such as observatories, planetariums, and museums.

Studies of curricular discussions/programs in astronomy (26.3%) are the second largest group. Here we find most of the suggestions about astronomy teaching and discussions about the insertion of astronomy into school curricula.

Works on the development and discussion of teaching materials (18.4%) constitute the third group. These are mainly authors of the papers that describe the use of various instruments for the teaching of astronomy content

Table 3. Distribution of the astronomy education papers presented at IAU meetings by school grade level.

Level	n	%
Elementary school	22	7.8
Middle school	30	10.6
High school	34	12.0
University education	107	37.8
Unspecified	96	33.9
Public outreach	78	27.6

Table 4. Distribution of the astronomy education papers presented at IAU meetings by focus of the study.

Focus	n	%
Nonschool programs	80	28.3
Curricular discussions and programs	75	26.3
Teaching materials	52	18.4
Learning and teaching	44	15.5
Teacher education	20	7.1
History of astronomy/History of astronomy education	14	4.9
Student and teacher understanding	9	3.2

such as telescopes, planetariums, and other didactic models; education software; and/or the analysis of astronomy content present in school books and related materials.

On the studies of learning and teaching of astronomy education (15.5%), we find works that authors present and discuss teaching methods for specific contents of astronomy at many school levels.

The works on teacher education (7.1%), dealing with projects and courses for teachers of different school levels, consisted of studies on the history of astronomy or history of astronomy education (4.9%). Studies that were related to students' or teachers' understanding (3.2%) complete the selected sample.

In summary, the studies devoted to astronomy education in the formal school context, realized by means of exhibitions, courses, visits to observatories, museums, planetariums, and other public places (and also in science olympics) are the most numerous and remarkable. There is also a large quantity of studies dealing with school practices and related material, which emphasize especially the work in the classroom.

With respect to the topics of content presented in papers, most studies do not deal with specific topics in astronomy; we labeled these as General (83.4%).

There are works that present the development of astronomy as a science and as a research area in some countries; reports of education experiences in museums, planetariums, observatories, and other centers; and proposed teaching programs on astronomy teaching. These do not focus on any specific content. Much less frequent are studies that deal with specific themes in astronomy, presenting many methods and materials about the education approach to themes such as the Sun–Earth–Moon System (6.7%), Stars (4.2%), Solar System (3.5%), and Sun (2.6%).

The category type of academic research was established based on the works of Asher (1976), Best (1967), Borg and Gall (1989), Charles (1988), Cohen and Manion (1989), Gay (1981), and Soares (1989). Based on this literature, we identified three kinds of academic work. The first kind, named Essays, corresponds to work that is theoretical in nature, in which the author expounds his ideas based on a selected theoretical framework. The second kind is related to work that developed as part of scientific research; it has clear investigative methodology. This second category is presented under various investigation models, which vary from author to author. Based on classical work in the field of scientific methodology of the human sciences or education, and in view of the works that we selected for classification, we developed the following categories: survey, empirical research, documental research based on content analysis, review (or state-of-the-art research), action research, and case study.

Finally, the third kind of academic work that we identified in the cited literature is related to what we will call Reports of Educational Experience. This consists of studies that result in some products or education objectives that produce a report about the developmental process. Frequently, the scientific literature is viewed as research and development (R&D). Also it has elements from various aspects of academic research and also can be regarded as academic research with a lower level of complexity (Beillerot 1991).

There are a variety of ways to consider the specific kinds of academic research. In an adaptation of authors, we proposed the following groups: reports of education experience (R&D, report of practice, etc.), essay, survey, empirical research, documental research based on content analysis, review, action research, and case study.

Table 5. Distribution of the astronomy education papers presented on IAU meetings by type of academic research.

Type of academic research	n	%
Reports of education experience (R&D, reports of practices, etc.)	191	67.5
Essay	58	20.5
Survey	25	8.8
Empirical research	6	2.1
Content analysis	4	1.4
Review	3	1.1
Action research	–	–
Case study	–	–

Table 5 shows the distribution of works by type of academic works used by the authors in the development of their investigations.

With respect to the type of academic research, the great majority of the papers were classified in reports of education experience (R&D, reports of practices, etc.) (67.5%). These papers presented reports on education experiences of the authors or reports of the current situation in astronomy education in their countries. Typical of researchers from the hard science areas are presentations of works without a deeper discussion of the theoretical framework or even their use of scientific methodology of data gathering.

The authors sometimes describe and analyze promoted/performed education practices in specific school or nonschool situations. In these cases, the author identifies a problem/deficiency situation of the learning–teaching process. However, they usually do not develop a systematic study about causes or factors that act in the process. These works are dedicated to the proposition and description of a proposal and, in some cases, to the report of its application.

The great incidence of works of the R&D type in IAU events, on the other hand, shows a great concern by a large number of authors in disseminating their experiences to their community, even considering that the works were not performed with the highest academic rigor.

The second largest group consists of Essays (20.5%), or free exposition of ideas in the field of astronomy education, with almost the total absence of references or explicit theoretical framework. Many of these works present a theoretical discussion of the introduction of astronomy contents in the school curricula. Other works reveal principles and fundamentals for astronomy education at a specific school level or in general. Still other works develop ideas or give references for training teachers who teach astronomy.

Typical types of education research such as survey (8.8%), empirical research (2.1%), documental research based on content analysis (1.4%), and review (1.1%) were not present significantly. In this context, studies of action research or case studies (see Cohen and Manion 1989) were not found at all. In this group of works, surveys are frequent, generally consisting of reports on the present stage of the development of astronomy education in many countries. This takes place in a general or specific context (for example, a particular university).

The works included in Survey are quantitative surveys about astronomy education in various countries, from a variety of sources (public schools, educational institutions, nonschool institutions such as museums, science centers and observatories, school curricular data, etc.). They characterize the current situation, or a particular historical period of education in astronomy, in that country.

Studies classified as Empirical Research consist of a proposition for training courses for teachers and students, implementation and evaluation of results on specific subjects of astronomy, or a particular theory of teaching and learning (mental models, for example).

Work involving documental research was based on content analysis that was conducted on textbooks having content relating to astronomy or mapped conceptions of students or teachers on topics of astronomy through questionnaires and/or interviews.

Review studies track the current state of scientific and academic knowledge in the field of astronomy education, from publications in journals or books on the ideas of students and teachers to teaching methods or other curricular or educational aspects.

Another remarkable result is the absence of a theoretical framework for the works. Among the 283 selected papers, 87.6% did not show any explicit theoretical references in the text. This absence is consistent with the fact that a great part of the works consist of action reports, that is, descriptions of situations related to astronomy education without the presentation of a systematic collection of data and, as a consequence, without analysis and discussion of this data within any theoretical framework. Even more surprising was finding many theoretical essays without any mention of the scientific literature; in such cases, there was a logical exposition of ideas about some subjects, but unfortunately without coordinating such ideas to present works in the academic/scientific forum. It is likely that these considerations could affect the studies and theories resulting from the scientific production in the field of astronomy education. If only very few works seek to obtain theoretical support in the scientific production of the area or correlated areas, then what is the significance of disseminating such a production widely? What is the significance of the events promoted by IAU and the corresponding proceedings, especially those related to the discussion about astronomy education? Should they be restricted to a simple exchange of experiences? Or should this production rather favor the elaboration of theories in astronomy education?

On the other hand, among the 35 works (12.4%) in which we find a theoretical framework, we did not find a concentration of one or more authors. The framework references are generally in the field of astronomy or astronomy education, or in science education or education in general. The area has used more internal references in the astronomy education or in related fields in the education arena.

5. CONCLUSIONS

IAU meetings have been characterized mainly by reports about practical education matters and exchange of experiences and not by scientific research in the field of education itself. The efforts to boost astronomy for public outreach and classrooms always benefit from exchange of experiences.

At the end of our survey and study presented here regarding accepted papers at IAU meetings, we have verified some limitations to the scientific methodology of these works and their theoretical frameworks. We believe that they contribute to the education of teachers and students at various school levels within developing the field of astronomy education. The wide education panorama of astronomy teaching, the exposition of programs, courses on astronomy made in schools or nonschool institutions, the exposition of a variety of education products (learning–teaching objects) in textbooks, experimental materials, and equipment for astronomy teaching, are some of the contributions that we found in these papers.

With regard to the scope and contribution of the IAU proceedings, in a survey in the Astronomy Education Review (AER) we found six references in five separate editions. Moreover, a book review (Gay 2005) was also published about the IAU proceedings (Teaching and Learning Astronomy, Pasachoff and Percy 2005) in volume 4, issue 2 of AER. Perhaps a broader survey, taking into account other journals or publications, in different countries, in the field of astronomy education, would show a wider range of papers from the IAU in the field of research and education in astronomy.

From the point of view of educational research, deeper treatments that deal with epistemological questions, teaching and learning processes proper for the area of astronomy at different school grade levels, and theoretical frameworks are necessary. These approaches could have the potential to stimulate the development of scientific investigations, as it does in other areas of knowledge.

At the same time, we suggest continuing the IAU support for the presentation of work, in its general assemblies or colloquia, directly related to astronomy education and the encouragement of participation of researchers in the field of education. This would undoubtedly contribute to the development of the field and its dissemination to the general public and support the schools at the basic level of global education.

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