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AUTOMATION AND RESEARCH COMPETENCE IN EXTRACURRICULAR ASTRONOMY ACTIVITIES FOR GIFTED STUDENTS.

Jan-Ovidiu TERCU, Vitalie CHISTOL

Abstract: *The use of automated technologies in extracurricular astronomy activities contributes to increasing efficiency, saving time and facilitating the learning process. This paper presents the importance of training students' research skills through extracurricular astronomy activities and the role of automation in this educational process, the automatic technologies used in astronomy are discussed, such as GoTo telescopes, astrometric and photometric data processing software and other tools that facilitate observation and analysis of celestial objects. The paper explains and develops the contribution that students can have to the development of new technologies for automating astronomical observations after participating in extracurricular activities in the future, if they will pursue a career in the field of astronomy and astrophysics.*

Key words: *automation, research competence, gifted students, GoTo telescope, CCD camera, extracurricular astronomy activities.*

1. INTRODUCTION

Although there is abundant literature on the importance of developing research skills through extracurricular activities, as well as the role of pedagogy in the education of gifted students, to date there has been no study that explores the impact of automation on this process within the framework of extracurricular astronomy activities. Therefore, this paper aims to fill this gap and provide an innovative framework for understanding and improving educational practices in the interconnected fields of pedagogy, astronomy, and technology. In the current technological era, education continues to evolve and adapt to the needs of society and students. Extracurricular activities, especially those in the field of science, such as astronomy, provide an excellent opportunity for the development of research competence in gifted students. They allow students to develop critical thinking skills, problem-solving abilities, and collaboration, which are essential for their future success. Gifted students have a high potential for learning and achievement in various fields, including science.

Gifted students in astronomy are talented young individuals who exhibit an exceptional level of understanding and passion for the study of cosmic phenomena, possessing superior observation, analysis, and abstract thinking skills that enable them to develop innovative ideas and significantly contribute to the advancement of knowledge in the field of astronomy, both through theoretical exploration and practical application of specific concepts and techniques in this fascinating field of science.

By their involvement in extracurricular astronomy activities, these students have the opportunity to develop their research skills and extend their knowledge in the field of space sciences. The development of these skills is important to help gifted students become leaders and innovators in their field of interest, thus contributing to scientific and technological progress. Automation, that is, the use of advanced technologies to perform complex tasks

without human intervention, plays a significant role in the development of research competence in gifted students. Through automation, students can interact with advanced learning tools, such as telescopes and software for reducing and analyzing astronomical data, which allow them to conduct autonomous research and discover new aspects of the universe. Automated GoTo telescopes and CCD cameras enable gifted students to observe and analyze different astronomical phenomena, such as the movement of asteroids, the variation in star brightness, and supernova explosions.

Through these tools, students can develop advanced research skills and better understand the complexity of the universe. Astronomical data reduction and analysis software allows gifted students to process and interpret the information obtained through automated telescopes. These may include, for example, determining the positions of asteroids and comets, monitoring variable stars, and identifying rare cosmic events.

Using these software, students can enhance their analytical and synthesis skills, as well as their communication and research results presentation competencies. Automation can be integrated into group activities within extracurricular astronomy activities, facilitating collaboration and communication among gifted students. For instance, students can use online platforms to plan and coordinate research projects, analyze the obtained data, and share their findings with peers and the scientific community. Automation can stimulate the curiosity and interest of gifted students in astronomy, as it allows them to explore complex topics and discover new aspects of the universe in an accessible and efficient manner. Thus, students can develop a positive attitude towards learning and research, as well as a desire to engage in long-term scientific activities.

Extracurricular activities encompass a wide range of programs and initiatives that take place outside school hours and complement the school curriculum. These include astroclubs, competitions, research projects, astronomy camps, and similar events. By participating in such activities, students gain new knowledge and skills, develop their creativity and critical thinking, improve social relationships, and gain a deeper understanding of the surrounding world. Participation in extracurricular activities is associated with a number of benefits for students, including better academic performance, a lower dropout rate, and greater involvement in volunteer and leadership activities. These activities also provide opportunities for the development of research skills, which are crucial for success in higher education and in scientific and technological careers.

To support the development of research competence in gifted students within extracurricular activities, collaboration between schools, planetariums, public astronomical observatories, associations of amateur astronomers, and the community is essential. By creating partnerships and joint programs, these entities can provide the resources, expertise, and support needed to develop and implement high-quality extracurricular activities in the field of astronomy and other sciences.

Technology and innovation play an important role in facilitating and enhancing extracurricular activities and the formation of research competence. Online platforms, mobile applications, and other digital tools enable students to access and engage in learning activities outside the classrooms, collaborate with peers, and share their research findings with the scientific community.

Implementing extracurricular activities in the field of astronomy involves a series of challenges and opportunities. One of the major challenges is ensuring equal access to resources and opportunities for all students, regardless of their socio-economic, geographic, or cultural background. Extracurricular astronomy activities provide valuable opportunities for students to engage in interdisciplinary research projects and collaborate with experts from different fields. For instance, a research project in astronomy may involve elements of physics, mathematics, computer science, and engineering, allowing gifted students to develop their research skills in a broad context and acquire an integrated understanding of the sciences. Parents and the community play a vital role in supporting extracurricular astronomy activities and the development of research competence in gifted students. Through active

involvement in their children's school life, parents can contribute to the development of their interests and abilities in the field of astronomy. The community can provide resources, expertise, and support for organizing events and extracurricular activities in this field, thus enriching the learning experience of gifted students and fostering the development of research competence.

2. AUTOMATION IN ASTRONOMY AND THE DEVELOPMENT OF RESEARCH SKILLS IN GIFTED STUDENTS

2.1 Description of automated technologies used in astronomy

Today, automation plays a crucial role in astronomy, facilitating research and scientific discoveries. Automated telescopes are a significant example of technology used in this field. They allow observation and image acquisition autonomously, without the need for constant human supervision.

Technology has played a significant role over time in the development and progress of astronomy. In particular, automation has revolutionized the way astronomers study the universe. An example of such technology is the GoTo automated telescope, which can be programmed to track celestial objects across the sky without human intervention. These telescopes can be equipped with high-resolution digital cameras that can capture images of cosmic objects, such as planets, stars, galaxies, and nebulae. Moreover, these telescopes can be remotely controlled, allowing students to use them for astronomical observations without physically being at the location.

The GoTo telescope is a type of telescope that has an embedded computerized system, capable of automatically locating astronomical objects in the sky. The name GoTo is derived from this telescope's ability to "go to" a specific object in the sky with just a few button presses.

These telescopes are equipped with motors on both axes (right ascension and declination) that enable the telescope's movement. An internal computer has a database with the coordinates of thousands of astronomical objects. When a user selects an object from this database, the telescope automatically moves to the selected object.

To function correctly, a GoTo telescope first needs to be aligned. This process involves entering a series of data, such as location (latitude and longitude), the exact date and time. In addition, most GoTo telescopes also require alignment with one or more bright known stars.

GoTo telescopes are extremely useful in astronomy education, as they simplify the process of finding celestial objects. They also allow for the automatic tracking of objects as they seemingly move across the sky due to the Earth's rotation on its axis, a key feature for astrophotography.

However, GoTo telescopes can be more complex and expensive than traditional telescopes, as they require additional electronic and mechanical components. They may also require an electrical power source, though many models are now powered by batteries or rechargeable batteries for portability.

Despite these challenges, GoTo telescopes continue to be a valuable resource for astronomy education, providing an accessible and efficient method of exploring the universe.

Connecting a GoTo telescope to a computer can open a wide range of possibilities, including controlling the telescope through computer software and acquiring images through a camera attached to the telescope.

Connecting a Charge-Coupled Device (CCD) camera to a GoTo telescope is straightforward but also requires some basic knowledge about the operation of both the telescope and the camera.

The CCD camera is widely used in scientific investigations in the field of astronomy. This instrument is equipped with a CCD sensor, which is an electronic device made of silicon. This CCD sensor consists of a multitude of photosensitive elements, called pixels, arranged in a matrix structure of rows and columns. Pixels are square-shaped, and their dimensions are measured in microns.

The resolution of the CCD camera, or its ability to capture fine details, is determined by the number of pixels and their size. A crucial parameter of the CCD camera is quantum efficiency, which is characterized as the ratio

between the average number of photons detected per unit area of the CCD sensor in a second and the average number of photons that fall on the same surface in the same time interval.

The quantum efficiency of the CCD camera can vary between 40% and 98%, compared to the quantum efficiency of the human eye, which is only 1%. This reflects the significant superiority of the CCD device compared to the sensory capacity of the human eye in terms of detecting radiation [1].

A GoTo telescope and a CCD camera can work together to provide an automated and interactive astronomical observing experience for gifted students. Before starting observations, the students, along with their teachers, decide what celestial objects they want to observe.

Once a list of observable objects is established, the GoTo telescope can be commanded to automatically point towards the selected celestial body. The telescope uses a coordinate system to locate the object in the sky and motors to move in the correct direction. Once the telescope is aligned with the object, the camera can begin acquiring images.

By using the CCD camera and the automatic functionalities offered by different software used for image acquisition, students can control and program the CCD camera to perform automated image acquisitions. This allows obtaining repeated series of images, necessary to analyze and detect variations in brightness or position of an astronomical object. The CCD camera has the ability to collect and record light coming from various celestial bodies, thus replacing visual observations with a more technical and advanced approach.

The images acquired by the CCD camera can be analyzed using specialized software. This can allow students to measure different properties of celestial objects, such as brightness, position, and movement. This can help develop students' research skills, as they can conduct their own astronomical research and interpret the results.

Students can present the results of their observations and analyses, discussing what they have learned and the significance of their discoveries. This can solidify their astronomy knowledge and develop the scientific communication skills of gifted students.

An important aspect to remember is that although the GoTo telescope and the CCD camera can automate many aspects of astronomical observations, there is still a significant need for guidance and mentoring from teachers or mentors. They can help students understand the principles underlying astronomical observations, as well as how scientific data reduction and analysis are conducted.

2.2 The Benefits of Automation for Developing the Research Skills of Gifted Students

Automation in astronomical observations, particularly the use of a GoTo telescope and a CCD camera, can offer many benefits in developing the research skills of gifted students within the framework of extracurricular astronomy activities. These benefits include:

- Familiarizing students with modern technology. Learning to use the GoTo telescope and CCD camera gives students the opportunity to become acquainted with modern technology used in astronomical research. This helps them understand how these tools can be used to collect and analyze data, thereby developing practical skills relevant to the field of science;
- Improving planning and organization skills. The process of preparing observations, configuring the telescope and camera, and planning and executing observation sessions requires good planning and organization. These skills are essential in research and can be transferred to other fields as well;
- Familiarizing with scientific methods. Using a GoTo telescope and a CCD camera involves applying scientific methods, such as data reduction and analysis, and interpreting the results. This can help students understand the scientific process and develop critical and analytical thinking;
- Developing problem-solving abilities. In the process of using a GoTo telescope and a CCD camera, various problems may arise, such as incorrect telescope alignment or camera issues. Solving these problems requires creative thinking and problem-solving skills, which are essential in research;

- Opportunities for independent research. With a GoTo telescope and a CCD camera, students can carry out their own observations and can collect and analyze their own data. This gives them the opportunity to conduct their own research projects and to develop a deeper understanding of the subjects they are studying;
- Encouraging curiosity and exploration. Observing the starry sky through a GoTo telescope and a CCD camera can spark students' curiosity and encourage them to explore and learn more about the universe.

Through the use of a GoTo telescope and a CCD camera, the following scientific investigations can be conducted within the extracurricular educational programs of gifted students:

- Conducting astrometric observations of asteroids and comets to determine the position of these celestial bodies;
- Photometric observations aimed at determining the rotation period and brightness amplitude of asteroids;
- Carrying out astrometric observations of visual binary stars to calculate separation and position angle;
- Photometric observations to determine the period and brightness amplitude of variable stars;
- Conducting astrometric and photometric observations of supernovae to measure their position and brightness;
- Carrying out photometric observations of exoplanet transits [1].

2.3 Pedagogical Approaches and the Role of Teachers and Mentors in Integrating Automated Technologies into Extracurricular Astronomy Activities

The integration of automated technology into extracurricular astronomy activities requires a well-thought-out pedagogical approach and the active involvement of teachers and mentors. They play a crucial role in facilitating understanding, exploration, and efficient use of this technology by gifted students. Below are some aspects about the role of teachers and mentors in integrating automated technologies into extracurricular astronomy activities:

- Differentiated education. Teachers and mentors need to recognize that gifted students may have different learning needs and may progress at a different pace than other students. Using a GoTo telescope and a CCD camera can provide personalized learning opportunities, allowing gifted students to explore and delve into the field of astronomy at their own pace;
- Skill development. Teachers and mentors must ensure that gifted students acquire the necessary skills to use automated technology efficiently. This could involve training students in setting up the telescope and the CCD camera, as well as using the camera and telescope control software. Teachers and mentors could encourage gifted students to experiment with different settings and techniques to develop a deeper understanding of how these tools can be used for astronomical observations;
- Promoting independent research and exploration. Teachers and mentors should encourage gifted students to use automated technology to conduct their own astronomical research and exploration. This could involve identifying their own targets for observation, processing and analyzing their own data, and even developing their own research projects;
- Mentorship and support. Teachers and mentors play a crucial role in providing ongoing support and guidance to gifted students as they develop their skills in astronomy. This could involve answering questions, providing feedback and assistance in solving technical problems, as well as encouraging and continuously supporting students' interest and enthusiasm for astronomy.

3. RESULTS AND DISCUSSIONS

At the Astronomical Observatory within the "Răsvan Angheluță" Natural Science Museum Complex in Galați, a set of extracurricular activities were initiated and carried out as part of a pedagogical experiment, focusing on the involvement of an experimental group of gifted students. This pedagogical experiment aimed at developing the investigative competence of

gifted students through extracurricular astronomy activities. These activities benefited from the equipment available within the astronomical observatory. The pre-established objectives for these research-based extracurricular activities of gifted students were as follows:

- Astrometric observation of asteroids and comets;
- Astrometric observation of visual double stars;
- Photometric observation of variable stars;
- Photometric observation of exoplanet transits;
- Detection and observation of supernovae.

To achieve these objectives, the following practical activities were carried out:

- Online astrometric and photometric observation sessions, in which gifted students played an active role. The pedagogical purpose pursued through these sessions was the formation and development of skills necessary for the use of Autoslew [2] and MaxIm DL programs, essential in controlling the telescope and the CCD camera, as well as in the process of acquiring and calibrating images. The practical component of the activities was conducted through the remote desktop application AnyDesk [3], facilitating the use of the following equipment: a Ritchey–Chrétien type telescope, with a 0.4 m diameter main mirror and an f/8 focal ratio, a German type ASA Direct Drive DDM 85 equatorial mount, as well as a SBIG STL-6303E CCD camera. The use of the AnyDesk application facilitated remote control of the telescope and the CCD camera by students, allowing for astrometric and photometric observations in an online environment. The process of remote astronomical observation involved each student accessing the desktop of the computer connected to the telescope and the CCD camera via the AnyDesk application. The MaxIm DL program was used to input the equatorial coordinates of the targeted astronomical object, which were obtained from celestial object catalogs or specialized online resources. The introduction of the coordinates was followed by the GoTo command, which resulted in the automatic movement of the telescope towards the target object. As for making observations through the CCD camera, students were instructed in the telescope focusing process. They used the Maxim DL software to configure the CCD camera, setting parameters such as exposure time, photometric filter, the number of necessary images, and the file for saving images. After acquiring the images, they were calibrated with flat, dark, and bias frames. Image calibration is an essential process to ensure the accuracy and reliability of the resulting data. This process involves several steps of correcting raw images to eliminate various types of noise and distortions that can affect them. [4].
- Data Reduction and Scientific Analysis conducted together with gifted students. The pedagogical purpose of these activities was the formation and development of skills necessary for the use of programs such as Astrometrica [5], AstroImageJ [6], Peranso [7] and VStar [8], which are indispensable tools in reducing astrometric and photometric data and in analyzing light curves (Figure 1).

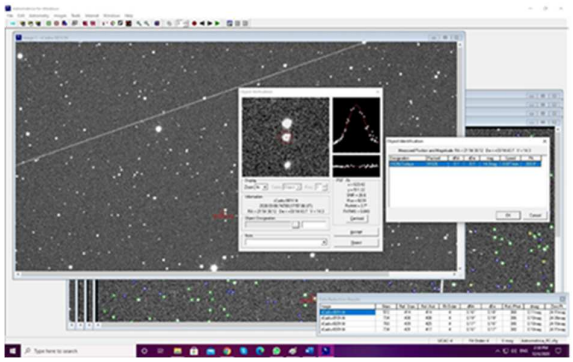

Fig.1. Screenshot taken while using Astrometrica software.
Credit: Astronomical Observatory of the "Răsvan Angheluță" Natural Sciences Museum Complex Galați

The activities were conducted through the Google Meet video communication service. During these sessions, both images obtained from astronomical observations and images taken from the database of the Galați Astronomical Observatory were used.

Automation has had a significant impact on students' performance, involvement, and interest in astronomical activities. The students actively participated in the online astrometric and photometric observation sessions, where they

used programs like Autoslew and MaxIm DL for controlling the telescope and CCD camera. This kind of direct and active involvement can be stimulating and engaging for students, as it allows them to partake in the actual process of research.

Automation also enabled the execution of astronomical observations in an online environment, which made the activity more accessible for students and facilitated their involvement, even from a distance. Automation contributed to the improvement of students' performance, as it streamlined the process of astronomical observation and allowed for better data collection and analysis. The pedagogical strategies used to integrate automated technologies into extracurricular astronomy activities were focused on active student involvement and the development of the skills necessary for using these technologies.

4. CONCLUSION

This article highlights the significant impact of automation on the development of research competence in gifted students who have participated in extracurricular astronomy activities. Automation has proven to be an essential tool in facilitating scientific data analysis and in deepening the exploration of astronomical phenomena. Using these technologies, students have been able to understand and explore astronomical concepts more deeply in an interactive and engaging way, thereby stimulating their curiosity and creativity in the field of research.

Automation in extracurricular astronomy activities has encouraged critical thinking and allowed for precision in observation and investigation. Improvement of infrastructure and the development of interactive online platforms can contribute to the expansion and diversification of extracurricular astronomy activities, providing more opportunities for gifted students to develop their research skills and explore their passion for astronomy.

Through these activities, students have not only learned about astronomical phenomena but also had the opportunity to apply their theoretical knowledge in a practical environment. This has actively and directly involved them in the learning process. In the course of these extracurricular activities, gifted students have had the chance to directly interact with the GoTo telescope and CCD camera, to explore, make mistakes, and learn through direct experience. Through such activities, students have been encouraged to think critically, collaborate, and develop their practical and cognitive skills. The integration of automation in extracurricular astronomy activities has contributed not only to the formation of research competence in gifted students but also has had a positive impact in stimulating their passion for science and exploration. These activities play a crucial role in the future development of young people in the field of STEM sciences and contribute to preparing future generations of researchers and space explorers. Automation facilitates the making of precise observations and data analysis, and multidisciplinary integration and constant updating of resources and teaching methods contribute to maximizing the impact of these activities.

Main Findings:

• Automation enriches the learning experience by providing sophisticated tools for precise astronomical observations and scientific data analysis.

• Technology promotes critical thinking, problem-solving, and scientific data interpretation.

Multidisciplinary Integration and Continuous Updates:

• Encouraging multidisciplinary integration allows students to make connections between sciences such as computer science, mathematics, physics, and astronomy for a holistic educational experience.

• Continuous updating of educational resources and teaching methods in astronomy is essential for maximizing the benefits of automation.

Recommendations for Future Extracurricular Activities:

• Development of specialized astronomy educational programs, tailored to the needs of students.

• Training of teaching staff to guide the efficient use of automated astronomy technologies.

• Collaborations between educational institutions, educators, and astronomy specialists to enrich these programs, keeping them current and with a high impact on students.

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Rolul automatizării în formarea competenței de cercetare a elevilor dotați în cadrul activităților extrașcolare de astronomie

Abstract. Utilizarea tehnologiilor automate în activitățile extrașcolare de astronomie contribuie la creșterea eficienței, economisirea timpului și facilitarea procesului de învățare. În prezenta lucrare este prezentată importanța formării competențelor de cercetare la elevi prin activități extrașcolare de astronomie si rolul automatizării in acest proces educațional, sunt discutate tehnologiile automate utilizate în astronomie, precum telescoapele GoTo, softurile de procesare a datelor astrometrice si fotometrice și alte instrumente care facilitează observarea și analiza obiectelor cerești. În lucrare este explicată si dezvoltată contribuția pe care o pot avea elevii la dezvoltarea de noi tehnologii de automatizare a observațiilor astronomice in urma participării la activități extrașcolare in viitor, daca vor urma o cariera in domeniul astronomiei si astrofizicii.

Jan-Ovidiu TERCU,

1. Planetarium/Astronomical Observatory Department, "Răsvan Angheluță" Museum Complex of Natural Sciences, Galați, 800340, Romania, ovidiu.tercu@gmail.com
2. Doctoral School Sciences of Education, "Ion Creangă" State Pedagogical University, Chișinău, MD-2069, Republic of Moldova

Vitalie CHISTOL, Astronomical Observatory and Planetarium TUM, Chișinău, MD-2004, Republic of Moldova, vitalie.chistol@astro.utm.md