NEW GENERATION OPEN SCIENCE PRACTICES AS SOURCES OF INSPIRATION FOR STEAM

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НОВО ПОКОЛЕНИЕ ПРАКТИКИ ОТ ОТВОРЕНАТА НАУКА КАТО ИЗТОЧНИЦИ НА STEAM ВДЪХНОВЕНИЕ

Abstract

In this article the new generation open science principles (open access, open data, collaboration, synergy, shared values) are represented as trends in scientific research and ideas for usage in education are demonstrated as a model for practices in STEAM education. Some specific examples will be given using openUC2 repository for students in universities and in high schools. OpenUC2 is remarkable concept, frameworks and standards for an open, modular and extensible optical toolkit for: education, rapid prototyping, scientific and applied research instrument. Applying open science principles to STEAM learning guarantees sustainable results if it is developed in research-based ecosystem.

Keywords: *Open Science; STEAM; openUC2; Research-based Ecosystems.*

INTRODUCTION

The open movement and its related fields (open-source software, open science, open design) are based on the principles of accessibility, reproducibility, reuse and remix, and improvement. In this domains, open science, open-source software and open design have a particularly important connection with the concept of STEAM. On the one hand, the open movement can provide inexpensive tools and methods for application in STEAM education in various educational projects, and on the other, the very process of implementation of implementing specific tools, methodologies, and practices can itself be in itself an educational project for multi-purpose training in certain related areas of mathematics, engineering, sciences, computer and data science and arts.

Figure 1. UC2 logo.

The article gives ideas, explanation, shares practices in using open science approaches that can be applied in bigger scale to receive more and better results in learning and research, using UC2 [1] (optical toolbox) examples. Fig. 1 shows the UC2 logo.

I. Open Initiatives, Policies, Practices, Standards

This section examines open (data, practices, science, software, and hardware), and aligns the UC2 to them by providing benefits and prospects

Open knowledge is any content, information or data that people are free to use, re-use and redistribute — without any legal, tech or social restriction [2]. The Open Knowledge Foundation not only provides definitions, but also develops and promotes tools like the Open Data Editor (ODE) - a free, open-source tool designed to help nonprofits, data journalists, activists, and government officials find errors in their datasets without coding [2]. In general, open means anyone can freely access, use, modify, and share for any purpose (subject, at most, to requirements that preserve provenance and openness) [3] and the term open source refers to something people can modify and share because its design is publicly accessible [4]. Many communities are attempting to promote open practices, like the Open Source Way group, which offers advice to anyone interested in establishing open source communities [5]. In Open Source Way guidelines [5] there is also important analyses for the reasons why people and organizations participate in such communities: for individuals (positive reputation, to sharpen their skills by working alongside and learning from others, to collaboratively solve problems, belief in the importance of contributing, for the purpose of socializing, or for a sense of identity and affiliation) and for companies (like the software they've developed to become an industry-wide standard, allows them to access a wider talent pool, collaborating on mutually beneficial software applications or standards is more valuable than competing to develop different, perhaps incompatible, technologies).

The experience of open communities (white paper [5]), including products that demonstrate both competitiveness and sustainability of development through communities (such as Linux), gave us some ideas for transferring the conclusions to newly formed STEAM communities or alliances of existing STEM-related organizations. Building such communities on a global scale addresses global problems of the planet, while local communities work on career guidance in STEM professions, attracting scientists, politicians and communities at the local level to use local assets for faster and more sustainable results. In this regard, existing small research-based ecosystems, such as Biomed-Varna [6] (founded by Momcheva and Pavlov initially as an ecosystem in 2019), are an example of a nucleus through which larger networks are built and practices are consolidated with other communities and organizations. STEM is much more than using ready-made lessons in school. The presence of an expert network contributes to deepening practices, achievements and real solving of existing problems (human resource development and infrastructure and community development). Because volunteer, open communities solve problems more quickly than politicians, the application of new technology and scientific advancements in the fields of artificial intelligence and computer science can put communities on a different level and make them far more significant [7].

The Open Source Hardware Association (OSHWA) seeks to promote accessible, cooperative, and user-freedom-respecting technological knowledge and research [8].

The steps to register open source hardware in OSHWA are listed as Open Source Hardware Checklist. The ID for this registration can be received after several steps:

- register your project with the Open Source Hardware Association (OSHWA);
- accepting OSHWA terms and conditions;
- apply for an OKEY (Open Hardware Key) to get a unique product ID, and the received key links physical device to documentation, designers, and public license through OSHWA's services.

The registered products can use Open Source Hardware logo (given in Fig. 2).

Figure 2. Open Source Hardware Association (OSHWA) Logo.

Some trends are visible for such communities, for example, they can easily move towards new directions of specialization that are important for society. For example, the OSHWA 2025 conference Open Healthware Conference [9] (August 25, 2025) presented and discussed topics like: 3D (open source medical supplies, 3D Printed Tungsten Shielding, Medical Prototyping at the Bedside, Portable and open medical imaging, 3D prosthesis), neuro-brain (bridging the body and the brain using FAIR principles, an open source active implantable medical device, a portable, open-source, multitool for cranial nerve examination), business and entrepreneurship (healthware business models open source prospects, high-risk device initiative, democratization of manufacturing) and building a foundation for Open Healthware - a community-driven platform to make medical technology more accessible.

The OSHW Certification Mark shows the project's unique certification ID and makes it easy for users to quickly find the project's details. This mark can be used throughout the design, documentation and promotional materials of the project. UC2 receives the Open Hardware (CERN) 2021 OSHWA UID certificate (Fig. 3), where UC2 (You.See.Too) is defined as a general-purpose framework for building optical projects and connecting methods and technologies to provide customized solutions.

Figure 3. UC2 OSWA ID.

Building a microscope using UC2 is as easy as building a house out of Lego©, as the modular toolkit relies on commercially available components and 3D-printed building blocks. It provides an accessible tool for both education and research. In the OSHW registration identifier, UC2 is defined as a project of the type UC2, open science, open education, microscopy, optics, photonics, documentation [10]. That's why it is very suitable in research-based ecosystem where researchers and educators are working together. In such a way exploring the topic of young researchers from high schools or STEM centers is easier and more productive.

Of great importance for the development of both entrepreneurship and research is the use of open data [11]. Its importance is somehow extended, in a business direction, with the EU shared data [12] within the framework of the data initiative, FAIR data [13]. The problems with the wider use of these practices are related to the lack of information, practices and cultural peculiarities of some countries, including problems with the way of thinking about working together and yet prioritizing competition over cooperation to achieve more goals, which is also a key point to consider and added values to be achieved in and through STEAM.

At the same time, we cannot fail to note the importance of CC [14] and OER [15]. Creative Commons (CC) is an international nonprofit organization that empowers people to grow and sustain the thriving commons of shared knowledge and culture we need to address the world's most pressing challenges and create a brighter future for all [14]. In the CC website the resources for the standard is given and CC strategy 2025-2028 for development for the next three years [14]. OERs are widely promoted by UNESCO and MoEs in many counties.

Young professionals all across the world use platforms for promoting their work, and they frequently publish their work under CC in at the beginning of their careers [14]. This is a common practice among many artists, but many professionals in the fields of architecture and medical, such as Dr. Valchanov [16], who is a member of our research-based ecosystem, also use open design tools and repositories, which we care to promote both locally (via events) and internationally (through social networks). In order to share 3D models and give authors credit, the UC2 authors decided to use the Thingiverse platform. Everyone can use and download 3D models from this portal for free [17].

One of the particular issues with publishing and disseminating links to resources that we identified is the situation in which some URLs have been altered, such as when an educator uses a link (citing the resource in an article or blog, but the author changes the URL or deletes the resource, or the website is redesigned). Thus, this is a barrier to the techniques' sustainability as well as a visible issue.

Among the creative ideas related to 3D design and printing are the design and printing of entire villages (Global Village Construction Set) [18] to laboratories (equipment [19], [20]), DIY microfluidics [21], [22], where we print not equipment or learn to design, but entire environments (for living or for research), called OpenLabs and OpenLabWare. Here we also connect UC2 (microscopes, telescopes) to this topic and application. Regarding microscopy in general, low-cost microscopes for open science [23], open access light microscopy platform [24] and smart microscopy [25] are in the center of the research community's focus.

In conclusion, Open Science is the movement to make scientific research, data, and their dissemination accessible to everyone by utilizing practices like Open Access Publishing, Open Data, Open Source Software, and Citizen Science, as well as the principles of transparency, accessibility, collaboration, reproducibility, and inclusivity. Additionally, open science is mandated by UNESCO's suggested policy [26] and EU project calls [27] (Open Access to publications and FAIR data (Findable, Accessible, Interoperable, Reusable) with the notion of "as open as possible, as closed as necessary").

The technologies, standards, and communities mentioned above are some of the tools with which we can build Open Science.

II. UC2 FOR STEAM

UC2 is an open source modular toolkit for creating hardware projects based on functional optical blocks. Dr. Benedikt Diederich is the founder, heart and soul of the UC2 project, which bridges the gap between education and science by offering an alternative to standard tools - a common toolkit that can be used in both fields. The same basic hardware is intended to be used to teach photonics and its applications in an interactive way, and students could later use the same system in their own work to create prototypes. As a collaborative, community-driven project, UC2 benefits from the experience of its early adopters and its appeal for project-based courses. It is a collective effort of many researchers and students in which the key aspects of open-source hardware design are evaluated and summarized into a decision matrix defining the boundary conditions of the development. Special importance is given to improving accessibility of the toolbox by providing comprehensive documentation and lowering the entry barrier.

Nowadays, there are numerous initiatives that began as an effort to produce modular, open, and affordable substitutes for tools, laboratories, and techniques. These initiatives eventually grew into extensive scientific and educational ecosystems. One such example is the OpenUC2 project and ecosystem [28], [29]. The project represents an attempt to create a modular system for quick prototyping, research and education in optics and since its start in

2017 it developed into a “Raspberry Pi for optics” in the words of its creators. The system is based on a set of modular baseplates, cubes and inserts that can be assembled in any desired geometry to reproduce or prototype any desired optical experiment. The real power of the project is that the modules can be produced by any contemporary available way for custom manufacturing: 3D printing, mould injection and laser cutting. The project documentation includes detailed specifications and instructions, so that existing modules may be modified and new ones can be designed as needed. OpenUC2 is heavily focused on education and research at the same time.

Very thorough tutorials and workshops explaining the fundamentals of optics are available in the project's GitHub repository (docs) [30] and are intended for a variety of learners, including K–12 students, college students [31] and PhD candidates. Step-by-step instructions and explanations are available in the project's public archive [10] making it possible to replicate and execute the project. This methodical approach is instructive in its own right, offering clarifications on "side subjects" such as 3D printing mechanics and principles, GIT versioning, etc. that are necessary for the novice to put the modular system together and use it for their needs.

High-end scientific equipment (such as the openUC2 Light Sheet Fluorescence Microscope and FRAME, a fully automated and programmable microscope based on the UC2 modular architecture) and instructional sets (such as Dicovery Boxes) are among the listed configurations (ready for download, production, and assembly). All necessary models can be assembled and downloaded in.stl format for production with the use of an online configurator program [32].

Of course, at least presently, the listed instruments cannot completely replace high-level equipment that is supported and maintained by professional engineers and equipment producers to ensure reproducibility and consistency in the experiments. The strengths of such modular system as OpenUC2 are however in its accessibility. It can allow a laboratory, team etc. to take a foothold in the otherwise hard to access world of end-level optical instruments and gather enough experience and data to justify further development and expensive purchases. Additionally, it makes it relatively easy to prototype new experimental setups, new optical pathways and experiment with concepts and modifications in a way that no proprietary closed system can allow. For example, the existing commercial light sheet microscope systems cost more than €250 000. At the same time, the Lightsheet Box can be manufactured and assembled at costs ten to a hundred times lower (depending on the quality of the parts that are used). While we cannot expect for this system to fully compare in quality and ease of use to the commercial systems, it can still provide high-grade scientific imaging avoiding some of the limitations of the classical widefield fluorescence microscope. An added benefit is the basically unlimited opportunity for reassembly and modification for the prototyping and design of new types of experiments, impossible with a closed system.

Additionally, small experiments that are pertinent to the school level can be designed and demonstrated during science days and nights within a setup created, for instance, for student training. These experiments can then be implemented and disseminated through teacher trainings and seminars, in which the authors of this publication also actively participate. The issue of complexity and the need to understand a wide range of subjects and concepts in order to construct something comprehensive can be resolved by the ability to work remotely with the installations. This implies and demonstrates the necessity of community service. Researchers and educators can thus carry out collaborative STEAM activities using a combination of real and virtual tools, including the assistance of multiple mentors from various backgrounds, the involvement of students with varying ages, levels of expertise, and experience, and, last but not least, working on issues pertaining to problem-solving for individuals and their local communities.

Building open practices that address important subjects like sound and light and extend to multimodal experimentation is the viewpoint for STEAM, which is also a viewpoint for modern science. With UC2, this direction can be sufficiently implemented. This also addresses the shortcomings of some "ready-to-use resources" for STEAM, such as pre-made lessons that don't sufficiently challenge students, don't offer variety, and don't spark their curiosity because the experiment's steps are static, the methods are the same, and the outcomes are predictable.

In this sense, UC2's capabilities allow us to study current topics like colors [33], sounds, images, and electronics in the real and quantum world through research approaches. We can also create assignments and activities and formulate research questions, the answers to which are still unknown in science, which we can collectively search for in communities. Science should be taught to today's youth through experimentation, functionally rather than chronologically. In this approach, we can prepare students for learning every day of their life by bringing them closer to subjects like understanding paradigm shifts in Science (e.g., Newtonian-Einstein's or the new particles in the cosmos discovered at CERN) while they are still in school and university.

CONCLUSION

In this article, we present our experience and vision for using resources in STEM education through research communities and in the context of open science recommendations. Open tools, results, sharing of research resources and results, in line with ethical norms, are the foundation of preparing learners for new careers.

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