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Article

Implementation of open science practices to enhance academic resilience in students: Case of Ukraine

Iryna Simkova[1,*], Yuliana Lavrysh[2]

[1] Department of English Language for Humanities, Igor Sikorsky Kyiv Polytechnic Institute, 03056 Kyiv, Ukraine
[2] Department of English Language for Engineering, Igor Sikorsky Kyiv Polytechnic Institute, 03056 Kyiv, Ukraine
*** Corresponding author:** Iryna Simkova, isimkova@ukr.net

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Abstract: This paper explores how Open Science (OS) practices can help students build academic resilience, especially in light of the ongoing challenges in Ukraine due to the COVID-19 pandemic and the war. By incorporating OS principles—like Open Educational Resources (OER), collaborative efforts, and transparent assessment—the study illustrates how students cultivate adaptability, problem-solving abilities, and a sense of community. The authors analyze the principles of Open Science and resilient pedagogy strategies using theoretical and empirical methods. The study presents the results from observing the training and interviews with 54 Ukrainian students. Using a qualitative case study approach, the research examines students' involvement with OS practices in an English for Specific Purposes (ESP) course. The findings suggest that OS contributes to resilience by lowering knowledge barriers, fostering collaborative learning, and enhancing inclusivity. Nonetheless, the study also points out the importance of balancing openness with privacy considerations. The paper wraps up with practical suggestions for integrating OS into education to foster more equitable and resilient learning environments.

Keywords: Open Science; academic resilience; Open Educational Resources; collaborative learning; transparent assessment; inclusivity; resilient pedagogy

1. Introduction

The COVID-19 pandemic and the war conflict in Ukraine have underlined a need for resilient pedagogical frameworks that could help students and educators cope with disruptions and traumatic war consequences. The current shift to Open Science throughout the world has gained momentum to encompass resources such as OER, open data, open innovation, open evaluation, open collaborative research, and transparent methodologies in an attempt to democratize knowledge and make learning more inclusive [1]. This paper explores how integrating Open Science practices into the learning environment can help foster students' academic resilience by promoting adaptability, normalizing iterative learning, and reducing systemic barriers. Resilience in this sense means the capacity of students to work through academic challenges, adapt to changes, and overcome educational barriers. By combining Open Science practices and strategies of resilient pedagogy, we can create learning environments that empower students to take ownership of their education, collaborate with peers, accept failure as a natural part of the learning process, and experience equal educational opportunities despite disruptions and different academic background [2]. Importantly, these practices can also address systemic barriers, such as high textbook costs or limited access to research opportunities, which disproportionately affect students and reduce the level of inclusivity.

Therefore, we assume that Open Science practices align with the principles of resilient pedagogy, which emphasizes flexibility, accessibility, and student agency. For example, Open Educational Resources (OER) eliminate cost barriers and empower learners and educators to customize materials, while open research collaborations teach students to navigate setbacks inherent in scientific inquiry. However, the intersection of Open Science and resilience remains underexplored in academic literature, particularly regarding how these practices can systematically support students. This paper addresses this gap by proposing actionable strategies that link Open Science principles to resilience-building outcomes, grounded in inclusivity and universal design. This paper's goal is twofold. The first objective is to explore the connection between Open Science practices and resilient pedagogy strategies, focusing on how transparency, collaboration, and adaptability inherent in open methodologies equip Ukrainian students to navigate academic and personal challenges. The second objective is to propose recommendations on the practical integration of Open Science Practices into the educational process in Ukraine. By bridging Open Science (OS) and resilience theory, we imply to provide educators with evidence-based strategies to create learning environments that are both adaptive and equitable, preparing students to thrive in an era of rapid change and uncertainty.

In the era of technological advances, modern education is more than delivering content—it's about preparing students to analyze information critically, create a personal educational environment, and manage obstacles in an unpredictable world. Employment of OS practices is becoming more and more demanded by research communities in Ukraine. Early career researchers have emphasized their desire to practice OS because it can lead to more citations, media attention, and new cooperation opportunities [3].

Among Open Science practices Christensen et al. [4] define the following: Citizen science, open notebooks, collaborative bibliographies, open research infrastructures, crowdsourcing, open research methods, and protocols, data sharing, Open Science communities, FAIR data management, Open Science education, journal club, Open Science infrastructures, open access publishing, Open Science policymaking, open access research instruments/equipment, Open Science working groups, open code, open-source software, Open Educational Resources, participatory science, open evaluation, and peer review, preprints, open hardware, preregistration, open innovation, science outreach and communication, open lab books. Open Science practices offer a unique opportunity to do this by making learning more collaborative, transparent, and accessible [5,6]. For example, when students work together on open research projects, they learn to communicate, solve problems, and persist through challenges. When they use OER, they save money and adjust materials to their own learning styles. Sharing their work openly contributes to academic confidence development and a sense of belonging to a larger community.

According to the finding revealed by Fleming et al. [7] Open Science practices were successfully integrated into the teaching process. The authors implemented three open practices: preregistering studies, posting preprints, and sharing data. Respondents demonstrated positive attitudes toward each of the practices but low levels of implementation knowledge. The discussion on Open Science integration into educational practices is presented in Heck et al.'s study [8]. Researchers reported that

employment of open educational practices raised students' awareness of the Open Science concept and equipped them with the skills necessary to use Open Science practices.

Openness is a multifaceted concept with diverse applications and meanings, reflecting its flexibility and values of freedom, mistake tolerance, equity, and inclusivity, as highlighted in many studies. These values not only make education more inclusive [9] but also foster resilience—the ability to adapt, persist, and thrive in the face of challenges. The connection between openness and resilience becomes clear when we examine how open education equips learners to navigate challenges. Thus, inclusivity is a key component of resilience, as it provides individuals with the tools, they need to overcome obstacles and persist in their goals. Open Science practices allow learners to personalize their educational experiences to fit their unique needs and circumstances [10]. This flexibility fosters adaptability—a core aspect of resilience. Thus, our study aims to broaden the current knowledge about Open Science principles and explore how Open Science practices integrated into the Ukrainian learning environment can help foster students' academic resilience. With this in mind, we tried to study Open Science principles and resilient pedagogy strategies, select the topics and tools to introduce the OS principles into the ESP courses, and identify the impact of Open Science principles on resilience building in the Ukrainian educational environment.

2. Materials and methods

- General background of research:

A complex of interrelated scientific research methods has been used to achieve the study goals. The theoretical methods used in the study are the generalization of philosophical, psychological, and pedagogical literature to consider the theoretical backgrounds of Open Science principles and resilient pedagogy strategies; the comparative analysis to stipulate the distinctive features of Open Science; the description of the results to explain the students' involvement with OS practices in an English for Specific Purposes (ESP) course.

The empirical methods used in the study are the observation of the educational process in those classes where OS practices in ESP courses took place; the quantitative and qualitative analysis of experimental data to show the impact of OS practices on building the students' resilience, Cohen's kappa (κ) statistics, and the Kimp formula for checking the impact.

- Participants:

To illustrate the applicability of the OS practices considered above on building the students' resilience, the study was carried out among 54 undergraduate students. The undergraduate students are in their third year of study and majoring in engineering from the Radio Technical Faculty and Faculty of Instrument Engineering at Igor Sikorsky Kyiv Polytechnic Institute (Ukraine). The sample was divided into three groups of students (RA-31, PB-32, and RA-33) that were of similar size (18 students per group). Three groups participated in the testing study from September 2023 to May 2024. Since the students had to remain in pre-existing groups due to administrative constraints, we employed a matched groups design with a pre-test/post-test control as

the most practical and reliable option. Students had comparable English proficiency and academic performance. Students' participation was voluntary and they could stop participation without any academic consequences.

Two testing groups (RA-31 = Group 1, PB-32 = Group 2) of future engineers participated in the ESP course where the OS practices were introduced and one academic group (RA-33 = Group 3) of future engineers experienced ordinary ESP class (when no additional activities aimed at OS such as collaborative project work, transparent assessment methods, and open notebook usage were used).

To verify the efficiency of introduced open practices during the ESP course and the significance of the impact, Cohen's kappa (κ) statistics and Kimp formula were used.

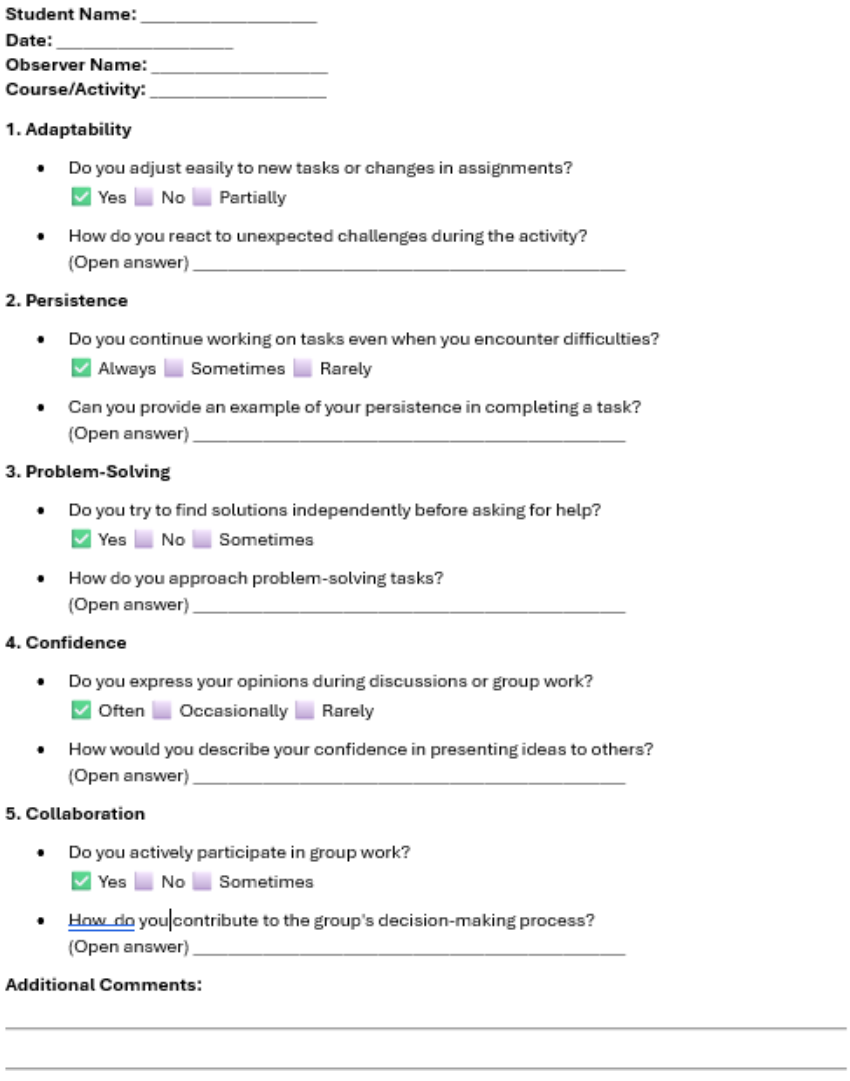
- Instrument and procedures:

The study employs a qualitative research design, observing and orally interviewing students. Essentially, this methodology aims to document real-time observations of how openness in education nurtures adaptability, inclusivity, and resilience. The research design is implemented within the theoretical underpinning of naturalistic inquiry, thus permitting an in-depth analysis of student experiences and behaviors in open learning environments. This research adopts a case study design with respect to a university course in which OS principles are practiced, using materials like Open Educational Resources, collaborative open research projects, and transparent assessment methods. The procedure of the study included three phases: preparation, implementation, and evaluation. During the preparation phase, we selected participants and developed educational materials, OER. The next phase took four months. It was the main phase for Open Science practices integration into the ESP courses. To collect data, we carried out peer feedback sessions, student interviews, observations, and transparent assessment strategies. The last evaluation phase included students' performance analysis, a resilience survey, and statistical validation.

This study attempted to integrate open educational practices within a third-year English for Specific Purposes course in order to gauge its effects on resilience. It evolved around three key open practices: collaborative project work, transparent assessment methods, and open notebook use. Students were divided into three groups and given real-world ESP tasks relevant to their specialism: writing a business proposal, case studies in management, or engineering report writing. They collaborated on open platforms, like Google Docs and Hypothesis, allowing for real-time sharing of drafts, comments, and resources, while also documenting their learning journey in public open-notebook-type settings, like blogs or wikis. Transparent assessments, including peer evaluation and open rubrics, were introduced to ensure fairness and encourage concrete feedback. Open publishing of final projects reinforced the sense of contribution and accountability. Throughout the entirety of the course, we provided regular check-ins and technical support to assist students in overcoming barriers to participation, ensuring that inclusion was paramount, with the option for students to decline public dissemination. At the end of the course, we collected student feedback through informal discussions and surveys that assessed the students' experiences of the various open practices. Our goal was to promote resilience by fostering adaptability, collaboration, and persistence while providing an inclusive and supportive learning environment in which students gain ownership of their learning.

The detailed description of activities is in the course description will be provided in the Discussion section.

We used an observation checklist (**Figure 1**) to ensure consistency, focusing on key indicators of resilience, such as adaptability, collaboration, and persistence. The analysis of observational data involved an examination of theme-specific field notes for patterns of student behavior and engagement. Themes of interest pertaining to resilience (adaptability, collaboration, persistence, etc.) were coded and categorized. Thematic analysis was used to derive themes and insights from the interview transcripts. Codes were built inductively focusing on students' perspectives on how open practices affected their resilience. A comparison of data distinguished from the observations and interviews enabled cross-checking for consistency and discrepancies to arrive at a thorough understanding of how openness may relate to resilience.



Student Name: _____
Date: _____
Observer Name: _____
Course/Activity: _____

1. Adaptability

- Do you adjust easily to new tasks or changes in assignments?
  ☑ Yes ☐ No ☐ Partially
- How do you react to unexpected challenges during the activity?
  (Open answer) _____

2. Persistence

- Do you continue working on tasks even when you encounter difficulties?
  ☑ Always ☐ Sometimes ☐ Rarely
- Can you provide an example of your persistence in completing a task?
  (Open answer) _____

3. Problem-Solving

- Do you try to find solutions independently before asking for help?
  ☑ Yes ☐ No ☐ Sometimes
- How do you approach problem-solving tasks?
  (Open answer) _____

4. Confidence

- Do you express your opinions during discussions or group work?
  ☑ Often ☐ Occasionally ☐ Rarely
- How would you describe your confidence in presenting ideas to others?
  (Open answer) _____

5. Collaboration

- Do you actively participate in group work?
  ☑ Yes ☐ No ☐ Sometimes
- How do you contribute to the group's decision-making process?
  (Open answer) _____

Additional Comments:

_____

_____

Figure 1. Observation checklist for assessing students' attitudes toward adaptability, persistence, problem-solving, confidence, and collaboration.

The coding process was performed in several stages. Firstly, codes were identified from key resilience concepts (adaptability, persistence, confidence, collaboration). Then we segmented the interview transcripts into meaningful

collocations and assigned them based on their relevance to indicators. After coding, we counted the frequency of code appearance in the content. To ensure consistency and reliability in coding, two experts independently coded 20% of the data. A high agreement level was achieved (Cohen's Kappa = 0.82), indicating strong reliability in the coding scheme. Cohen's Kappa is calculated as:

$$\kappa = \frac{\mathrm{Po}-\mathrm{Pe}}{1-\mathrm{Pe}}.$$

Given: observed agreement (Po) = 0.92 (coders agreed on 138 out of 150 instances), and expected agreement Pe = 0.90.

Given the case study parameters, the findings may not generalize to any or all educational contexts. On the other hand, they provide rich contextual information that may nurture future research. Oral feedback may suffer from social desirability bias; to address this, observational data were triangulated with student feedback.

As was mentioned to verify the significance of the impact of OS principles on the students' resilience building Cohen's kappa (κ) statistic was used. This chance-corrected method helped us to assess agreement (rather than association) among participants.

In our research, Cohen's kappa is defined as follows:

$$k = f\mathrm{o} - f\mathrm{E}/N - f\mathrm{E}.$$

where,

fo is the number of observed agreements between students, while

fE is the number of agreements expected by chance, and N is the total number of observations.

We examine our data in Goder 1 using kappa (recall that $N = 61$):

$$f\mathrm{o} = 34 + 25 = 59$$

$$f\mathrm{E} = 8.41 + 38.41 = 46.82$$

$$k = (59 - 46.82)/(61 - 46.82) = 0.86.$$

In Coder 2 (recall that $N = 55$):

$$f\mathrm{o} = 24 + 29 = 53$$

$$f\mathrm{E} = 6.56 + 34.44 = 41$$

$$k = (53 - 41)/(55 - 41) = 0.8.$$

In Coder 3 (recall that $N = 86$):

$$f\mathrm{o} = 31 + 53 = 84$$

$$f\mathrm{E} = 9.54 + 62.46 = 72$$

$$k = (84 - 72)/(86 - 72) = 0.8.$$

In Coder 4 (recall that $N = 36$):

$$f\mathrm{o} = 12 + 22 = 33$$

$$f\mathrm{E} = 2.44 + 19.08 = 21.52$$

$$k = (33 - 21.52)/(36 - 21.52) = 0.85.$$

In Coder 5 (recall that $N = 36$):

$$fo = 12 + 22 = 33$$

$$fE = 2.45 + 19.05 = 21.5$$

$$k = (33 - 21{,}5)/(36 - 21{,}5) = 0.79.$$

To verify the impact the following formula was used.

$$\text{Kimp} = \frac{C1 + C2 + C3 + C4 + \ldots}{\text{Ncod}}$$

where $C1$ = the results gained for Coder 1, $C2$ = the results gained for Coder 2 etc. and N cod = general number of Coders.

$$\text{Kimp} = \frac{0.86 + 0.8 + 0.8 + 0.85 + 0.79}{5} = 0.82.$$

The study incorporated semi-structured open interview questions to ensure a systematic and comprehensive data collection process. The semi-structured interviews aimed to capture students' perceptions of Open Science practices and their impact on resilience development. Key questions for the interview included:

1) Adaptability:
   - How do you typically respond to feedback on your work?
   - Can you describe a time when you made significant changes to your work based on peer or instructor feedback?
2) Persistence:
   - What challenges did you face while working with Open Science practices, and how did you overcome them?
   - Did you ever feel like giving up? What motivated you to continue?
3) Problem-Solving:
   - How did you handle difficulties in completing assignments using open collaborative platforms?
   - Did working openly help you improve your critical thinking skills?
4) Confidence:
   - How comfortable did you feel sharing your work on open platforms?
   - Did your confidence in your academic abilities change throughout the study?
5) Collaboration:
   - How did working in an open environment influence your teamwork skills?
   - Can you provide an example of a time when collaboration helped you improve your work?

These questions ensured that the study reflected both objective behavioral data and subjective student experiences, strengthening the reliability and depth of the findings.

3. Results

To analyze the empirical data, we studied student interviews and observation

notes using thematic content analysis. This involved coding qualitative data into categories related to resilience indicators (e.g., adaptability, persistence) and then quantifying the frequency to reveal patterns. We performed 54 semi-structured interviews. Codes were derived from the key resilience concepts [11–13]: adaptability, persistence, problem-solving, confidence, and collaboration. Each code occurrence was counted.

Table 1 provides an example of the frequency and distribution of codes across interviews and observations:

Table 1. An example of frequency and distribution of codes.

Resilience Indicator	Total instances (interviews)	Total instances (observations)	Combined frequency	Example quote/observation
Adaptability	27	18	45	"I had to rewrite my proposal three times after the feedback I got, and it is way better now." (Interview, Student 5)
Persistence	22	15	37	Observed: A group revised the project draft 5 times although the deadlines were very close. (Observation, Session 4)
Problem-solving	19	12	31	"When our group had tech issues, we could always find tutorials online to fix it." (Interview, Student 12)
Confidence	16	10	26	"Making our work available online made me feel proud of what I was capable of." (Interview, Student 8)
Collaboration	34	25	59	Observed: In open notebooks, students shared troubleshooting tips. (Observation, Session 7)

As we could see from the findings adaptability was the most frequently observed indicator (45 instances), when students actually edited the work after getting feedback. Collaboration had the highest combined frequency (59 instances), which is due to the use of open platforms that help to enhance teamwork. Confidence had the lowest frequency of occurrence (26 times), which means that although the use of open practices enhanced students' self-confidence, they still had some uncertainties regarding the sharing of their work in the public domain.

The content analysis demonstrates that open practices directly supported resilience development. The students would alter their work more often than not, with an average of 45 times for adaptability and 31 times for problem-solving. A student said, "Feedback from peers made me revisit my work and improve it step by step." However, despite some challenges like technical problems or different timing, 37 coded instances of persistence were observed. Students could revise their work as many times as necessary. Open collaborative platforms and peer evaluation contributed to the development of teamwork skills.

4. Discussion

The relevance of integrating open science practices into education in enhancing student engagement, resilience, and collaborative learning has currently gained significance. Resilience is defined as the ability to adapt to and overcome obstacles and challenges and is recognized as a critical skill for academic and personal success [14]. Open education offers an innovative platform for supporting resilience by giving learners access to knowledge, realization of joint work, and transparent assessment. By joining open research projects, students relate to authentic scientific inquiry while

developing essential problem-solving and coping skills. This paper discusses how open education and Open Science practices help in the development of resilience by providing students control, creating a sense of community, and encouraging flexible learning strategies. Our findings are in line with Lambert [15] who argues that Open Science practices are inherently aligned with social justice, as they promote equity, inclusivity, and access for marginalized learners.

From our observations, we can claim that students engaging in open research projects could learn to handle setbacks, as research often involves failure, and it helped to develop resilience skills. Open education empowers learners by giving them control over their learning journey. When students can access, adapt, and share resources, they develop a sense of ownership and confidence in their abilities. This empowerment helps them face challenges with a growth mindset, seeing setbacks as opportunities to learn and improve. Also, sharing their work openly fostered a sense of contribution and belonging to the community, which is beneficial for mental well-being and resilience. We suggested students participate in Open Science collaborative projects as this practice enhances resilience through teamwork and problem-solving [16].

We were surprised to find a fact that some teachers remain skeptical about Open Science due to concerns about recognition and quality assurance. Traditional publishing metrics, such as impact factors, continue to dominate academic evaluations, often discouraging scholars from engaging in open-access publishing. Promoting alternative metrics, such as the use of altimetric and open peer review, can help shift academic culture toward more inclusive and resilient research practices.

Nevertheless, we are of the point that Open Science has proven to be a crucial tool in responding to global crises. Open research frameworks have facilitated timely responses to military situations, climate change, humanitarian crises, and emerging infectious diseases. By ensuring immediate access to scientific findings, Open Science enables policymakers, practitioners, and researchers to make informed decisions swiftly, reinforcing the resilience of global knowledge systems [17].

One of the most significant advantages of Open Science in addressing global challenges is its ability to accelerate the dissemination of critical research findings. In traditional publishing models, the peer review and publication process can take months or even years, delaying the availability of crucial information. However, Open Science promotes immediate access to research through preprints, open-access journals, and data-sharing platforms. This rapid dissemination is particularly vital in times of crisis, allowing researchers, policymakers, and practitioners to access the latest scientific knowledge without barriers. For instance, when the full-scale war in Ukraine started in 2022, open data repositories enabled real-time cooperation of Ukrainian scientists with other scientists around the world, leading to faster and more effective collaboration in different fields of study. Similarly, in other countries experiencing natural disasters, climate scientists utilize open-access platforms to share data on rising temperatures, greenhouse gas emissions, and extreme weather patterns, ensuring that governments and organizations can implement timely mitigation measures [18]. It is crucial to note that Open Science has received much attention in the past decade as it fosters interdisciplinary and cross-sector collaboration, which is essential for tackling complex global issues [19]. Challenges such as war conflicts, climate change, pandemics, and humanitarian crises require input from multiple disciplines, including

medicine, social sciences, economics, and engineering. Open Science platforms encourage researchers from different fields to work together by providing unrestricted access to studies, datasets, and methodologies. This transparency helps create a more integrated and holistic approach to problem-solving, reducing duplication of efforts and maximizing the impact of research findings. For example, in the fight against antibiotic resistance, medical researchers, epidemiologists, and policy analysts collaborate through open-access publications and shared databases, ensuring a coordinated response to the growing public health threat.

In our ESP courses, we propose the following topics (**Table 2**).

Table 2. Structured ESP courses with OS principles and activities.

Month	Topic	Key Focus Areas	Tools/Activities
Sept.	Accessibility of Knowledge	How access to Open Educational Resources (OER) supports students' independent learning and fosters resilience in challenging circumstances.	Introduction to OS and OER concept Quizlet, Padlet
Oct	Collaboration and Peer Support	The role of open collaborative research and peer interaction in building a supportive community and enhancing emotional resilience.	Collaborative project work Zoom, MS Teams, GoogleMeet.
Nov	Transparency and Trust	How transparent methodologies and open assessment practices promote trust in learning processes and encourage persistence.	Transparent assessment Open notebook
Dec	Adaptability through Digital Tools	The impact of open digital platforms and open innovation on students' ability to adapt to new learning environments.	Google Forms
Jan	Problem-Solving Skills	Development of critical thinking and problem-solving abilities through access to open data and participatory knowledge creation.	Collaborative project work, Roleplay
Feb	Inclusivity and Equity	The influence of inclusive open science practices in promoting equal access to educational resources for marginalized groups.	Discussions, Round tables
March	Self-Efficacy	How involvement in open collaborative projects contributes to students' confidence in their abilities.	Google Forms
April	Knowledge Co-creation	The role of open peer review and open research platforms in engaging students in creating and sharing knowledge.	Canvas, Prezi Padlet
May	Digital Literacy	Improving technological skills through participation in open science platforms and open access resources.	Zoom, MS Teams, GoogleMeet. Quizlet, Padlet

Table 2 structured ESP courses with OS principles and activities. Moreover, Open Science enhances the adaptability and resilience of research communities by ensuring that scientific knowledge remains available despite institutional, political, or financial constraints. A challenging area for Open Science is considered regions affected by conflict, economic instability, or censorship, access to scientific literature is often limited, hindering progress and innovation. Some hypotheses regarding Open Science appear to be debatable, however, open-access initiatives help bridge these gaps by making high-quality research freely available to scholars and practitioners in resource-limited settings. While resilience refers to the ability to recover from setbacks and maintain emotional stability in the face of challenges, adaptability involves the capacity to adjust to new conditions and modify behavior or strategies in response to change. This inclusivity strengthens global research networks, empowering scientists and decision-makers to address pressing issues regardless of their geographic location or institutional affiliation. The increasing adoption of Open Science principles by

international organizations, universities, and funding agencies further reinforces the resilience of the global knowledge system, ensuring that essential research remains accessible and impactful even in the face of uncertainty.

This finding confirms that Open Science policies, such as the FAIR (Findable, Accessible, Interoperable, and Reusable) principles, support long-term data stewardship, enabling future generations of researchers to build upon existing work. Additionally, as was mentioned previously, Open Educational Resources (OERs) contribute to academic resilience by providing freely accessible learning materials and reducing the dependency on costly textbooks and proprietary databases [20].

The sustainability of academic literature is closely linked to the principles of continuous knowledge exchange, innovation, and equitable access. Open Science plays a crucial role in ensuring that scholarly work remains available for future research and development by promoting transparency, collaboration, and the free dissemination of knowledge. Traditional academic publishing models often impose financial and institutional barriers that limit access to essential research, particularly in low- and middle-income countries. Open-access policies break down these barriers, allowing a more diverse range of scholars to contribute to and benefit from existing knowledge. By making academic literature freely accessible, Open Science fosters a more inclusive and sustainable research ecosystem, ensuring that knowledge remains a shared global resource rather than a commodity restricted to privileged institutions.

By making research outputs more discoverable and reusable, the FAIR principles promote efficiency and reduce redundancy, ultimately contributing to the sustainability of academic literature. In fields such as environmental science and medicine, where long-term data tracking is crucial, adherence to FAIR principles enables researchers to analyze trends over time, improve predictive models, and develop more effective interventions.

Our study provides additional support for another important factor in the sustainability of academic literature—the role of Open Educational Resources, which provide freely accessible learning materials for students, educators, and independent researchers. Traditional academic resources, including textbooks and journal subscriptions, can be prohibitively expensive, limiting access to high-quality educational materials. OERs help mitigate this issue by offering openly licensed textbooks, lecture notes, and online courses that can be freely used, modified, and shared. These resources are particularly beneficial in underfunded institutions and developing countries, where access to expensive proprietary databases may be restricted. By promoting knowledge-sharing and lifelong learning, OERs enhance the resilience of the academic community and ensure that education remains accessible to all [21].

Furthermore, the sustainability of academic literature depends on institutional and policy support for Open Science initiatives. Universities, research institutions, and funding agencies must actively promote open-access publishing, data-sharing mandates, and FAIR-compliant repositories to maintain the integrity and longevity of scientific knowledge. Governments and international organizations can play a role by implementing policies that encourage open research practices and by providing funding for sustainable digital infrastructures. Additionally, collaboration between academia, industry, and nonprofit organizations can enhance knowledge sustainability

by fostering innovative solutions for data preservation and access. By institutionalizing Open Science policies and ensuring adequate funding, the academic community can safeguard the long-term availability of scholarly research, reinforcing the resilience of global knowledge systems in the face of evolving challenges [22–24].

Flexibility is a fundamental principle of Open Science, recognizing that there is no universal approach to practicing openness in research. Different disciplines, institutions, and cultural contexts have unique needs and constraints, requiring adaptable strategies to ensure that Open Science remains inclusive and effective. While the core values of transparency, accessibility, and collaboration remain central, researchers must have the freedom to implement Open Science practices in ways that align with their specific fields. For example, while open data sharing is widely encouraged, sensitive data in medical and social sciences may require restricted access or anonymization to protect privacy. By acknowledging these variations, Open Science fosters a more inclusive and practical framework that accommodates diverse research communities [25].

There is evidence to support the hypothesis that encouraging multiple pathways to Open Science ensures that researchers can engage with openness at different levels without compromising academic integrity or research quality. Some scholars may choose to publish in fully open-access journals, while others may share preprints, open their datasets selectively, or participate in open peer review. Additionally, disciplines such as engineering, physics, and humanities have distinct publication norms, requiring tailored approaches to open access and data-sharing practices. By allowing for flexibility in implementation, Open Science supports a broader adoption of open practices, making it easier for researchers to integrate openness into their work without feeling restricted by rigid policies. This adaptability ultimately strengthens the overall sustainability and impact of Open Science across different academic domains.

Maintaining flexibility in Open Science also means recognizing the challenges researchers face, such as funding limitations, intellectual property concerns, and institutional policies. Open access publishing, for instance, often involves article processing charges (APCs) that may be unaffordable for researchers from underfunded institutions. Alternative models, such as green open access (self-archiving) or diamond open access (no APCs), provide different ways to practice openness while ensuring financial inclusivity. Additionally, multilingual publication initiatives allow researchers to share knowledge in their native languages, addressing linguistic barriers in global scholarship. By promoting a flexible and context-sensitive approach, Open Science remains a dynamic and evolving movement that empowers researchers to engage with openness in ways that best suit their academic and societal needs [26].

We feel strongly that responsibility, respect, and accountability are essential principles of Open Science, ensuring that research is conducted with integrity, transparency, and awareness of its broader impact. Researchers have a duty to be mindful of public accountability, recognizing that scientific knowledge influences policy, industry, and society. By openly sharing data, methodologies, and findings, they contribute to a culture of trust and credibility in academia. However, this openness must be balanced with ethical considerations, such as protecting sensitive information, respecting participant privacy, and acknowledging potential risks associated with publicly accessible research. Upholding intellectual integrity requires

researchers to be honest about their methods, disclose potential biases, and ensure that their work meets the highest ethical and scientific standards [27].

In our opinion, respect in Open Science extends to collaborators, research participants, and the wider community. Open research practices should promote inclusivity and equity, ensuring that knowledge is shared in ways that benefit diverse populations rather than reinforcing existing disparities. This includes crediting contributors appropriately, acknowledging indigenous knowledge systems, and considering how research outcomes might affect marginalized communities. Additionally, respect for ecological sustainability is crucial, particularly in fields such as environmental science, where research activities may have direct consequences on ecosystems. Responsible data collection, ethical sourcing of materials, and minimizing the environmental impact of research are all aspects of a respectful and accountable approach to Open Science.

Accountability in Open Science also involves recognizing and addressing potential conflicts of interest that may influence research findings or dissemination. Transparency about funding sources, industry partnerships, and institutional affiliations is necessary to maintain public trust and prevent biases from shaping scientific conclusions. Researchers must also be aware of how their work is used, ensuring that open data and findings are not misinterpreted or misused for harmful purposes. This requires continuous engagement with policymakers, educators, and the general public to provide clear, responsible communication of scientific results. By embracing responsibility, respect, and accountability, Open Science strengthens the reliability of academic knowledge while promoting ethical and socially conscious research practices [28].

Transparent assessment methods imply open criteria and partnership with students while developing assessment rubrics. According to students' feedback, such practice reduced anxiety and promoted creative thinking skills [29]. Students also were asked to express their peer evaluation of collaborative projects on online open platforms. This strategy fostered a supportive community and helped create a safe learning environment. However, not all students were comfortable with open sharing. Therefore, we had to balance openness with inclusivity, allowing anonymous contributions or opt-out options. That way, we tried to respect student privacy while promoting openness.

5. Conclusion

The evidence from this study suggests the recommendations that can be introduced into the Ukrainian learning environment. Open Educational Resources can be used for adaptive learning. ESP teachers can replace traditional textbooks with OER and allow students to adjust them to their needs. It fosters flexibility as it allows students to access materials anytime, reducing stress and financial burden. Customizable resources support diverse learning needs. Collaborative open research projects with peers contribute to teamwork skills, persistence, and problem-solving skills. Such projects also boost motivation because they are relevant to students' interests and allow students to apply acquired skills in practice. It helps students feel confident and empowered, giving them agency over their learning and encouraging

them to contribute to public knowledge. Using open platforms for peer review created a supportive environment, reducing isolation and developing communication skills. Transparent and adaptive assessment practices, open rubrics, and iterative feedback cycles helped students understand expectations and learn from mistakes, fostering a growth mindset. Such practices reduce anxiety, clarify expectations, and provide a safe learning environment.

Thus, open education not only democratizes access to knowledge but also cultivates the resilience needed to thrive in an unpredictable world. By embracing openness, we create educational systems that are not only equitable but also empowering, preparing learners to face adversity with confidence, creativity, and adaptability.

This study highlights that Open Science practices enhance resilience in students by promoting adaptability, confidence, and collaborative commitment. Considerable progress has been made while observing the students learning and how open research projects help students cope with challenges, contribute to developing a growth mindset, and further facilitate student ownership over their learning experience. In addition, transparent assessment methods and peer evaluation within open platforms encourage a nurturing environment for learning by reducing anxiety levels and enhancing creativity.

Among key limitations, we outline sample size and generalizability. A relatively small sample (54 students) limits the ability to generalize the findings to the broader population. Another limitation deals with self-reported data which can introduce bias. Students may present themselves in a more favorable light. A few Open Science practices can also be considered as limitations. While the selected practices are significant, they may not capture the full breadth of OS principles.

Further work needs to be done with regard to maintaining the equilibrium between openness and inclusivity, it still has remained a challenge that demands sensitive avenues for ensuring student privacy and comfort. On the other hand, an Open Science approach aligned with principles of social justice states how truly transformative it could be for the democratization of education. Future studies may evaluate the extent to which open educational interventions could be made more conducive to the support of resilience under a variety of learning circumstances.

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