“Open science as an innovative educational tool for creativity and problem-solving in higher education: Implications for marketing-oriented learning”

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ARTICLE INFO	Nadiia Artyukhova, Artem Artyukhov, Robert Rehak, Maksym Zhytar, Milena Kirilova Filipova and Dou Shenggeng (2026). Open science as an innovative educational tool for creativity and problem-solving in higher education: Implications for marketing-oriented learning. *Innovative Marketing* , *22*(2), 348-373. doi:10.21511/im.22(2).2026.24
DOI	http://dx.doi.org/10.21511/im.22(2).2026.24
RELEASED ON	Tuesday, 16 June 2026
RECEIVED ON	Tuesday, 21 April 2026
ACCEPTED ON	Monday, 25 May 2026
LICENSE	This work is licensed under a Creative Commons Attribution 4.0 International License
JOURNAL	"Innovative Marketing "
ISSN PRINT	1814-2427
ISSN ONLINE	1816-6326
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
55	1	10

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine
www.businessperspectives.org

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OPEN SCIENCE AS AN INNOVATIVE EDUCATIONAL TOOL FOR CREATIVITY AND PROBLEM-SOLVING IN HIGHER EDUCATION: IMPLICATIONS FOR MARKETING-ORIENTED LEARNING

Type of the article: Research Article

Received on: 21st of April, 2026
Accepted on: 25th of May, 2026
Published on: 16th of June, 2026

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Conflict of interest statement:
Author(s) reported no conflict of interest

Abstract

Open science is increasingly recognized as an innovative educational tool for developing creativity, idea generation and problem-solving skills in higher education, with potential implications for marketing-oriented learning. This study examines how students' engagement with open science practices is associated with their perceptions of creativity and problem-solving with particular attention to open data, open educational resources, open scientific publications and barriers to adoption. The empirical analysis is based on a cross-sectional survey of 2,250 students from Ukrainian higher education institutions. Descriptive statistics, Spearman's rank correlation coefficients, a correlation matrix and ordinal logistic regression models were applied in RStudio. The results show that the frequency of open science use is positively associated with the overall perceived creative value of open science ($\rho = 0.498$, $p < 0.001$). Among specific open science elements, the strongest correlations with use frequency are observed for open data ($\rho = 0.295$), open educational resources ($\rho = 0.260$) and open scientific publications ($\rho = 0.240$). Ordinal logistic regression shows that the overall perceived creative value of open science is the factor most strongly associated with reported open science use ($\beta = 1.236$; OR = 3.440; $p < 0.001$), while open data and open educational resources are also positively associated with engagement. Barriers have weaker associations, although lack of instructor support is negatively related to students' perception of open science's creative value ($\beta = -0.092$; OR = 0.912; $p = 0.015$). The findings suggest that open science practices may support marketing-relevant competencies, including evidence-based thinking, data interpretation, creative communication and innovation-oriented problem-solving.

Keywords creativity, problem-solving, marketing education, higher education, open science, open educational resources, open data

JEL Classification I23, M31, O31, O33

INTRODUCTION

Innovative educational tools for creativity and problem-solving in marketing-oriented higher education are becoming increasingly relevant as universities are expected to prepare students not only to reproduce knowledge but also to generate ideas, interpret data, communicate evidence and develop solutions for complex market and societal challenges. In this context, open science offers a promising educational approach because it provides access to scientific publications, open data, open educational resources, software, research protocols and collaborative knowledge environments. UNESCO and the Canadian Commission for UNESCO (2022) define open science as an approach aimed at making scientific knowledge openly available, accessible and reusable, while its 2021 Recommendation on Open Science establishes a global framework for reducing knowledge divides and strengthening collaboration, transparency and inclusiveness in science.

Marketing-oriented higher education is increasingly shaped by the need to prepare students for data-driven decision-making, user-centered innovation, digital communication, evidence-based strategic thinking and interdisciplinary collaboration. The European Research Executive Agency (EREA, n.d.) emphasizes that open science is based on open, collaborative work and the early and widespread sharing of knowledge, results, and tools. At the same time, Horizon Europe promotes the principle "as open as possible, as closed as necessary". These priorities correspond directly to the needs of modern marketing education, where students must learn to work with open data, interpret scientific evidence, develop creative communication solutions and apply innovative tools to real-world problems. Therefore, open science can be considered not only a research policy priority but also an innovative educational tool for developing creativity, analytical thinking and problem-solving skills.

The study's relevance is further reinforced by OECD attention to creativity and critical thinking as key learning outcomes in higher education. Bouckaert's (2023) and Saroyan's (2022) works on creative and critical thinking highlight the need to foster and assess these skills systematically in university teaching and learning, rather than treating them as implicit outcomes of education. For marketing-oriented programs, this is particularly significant because creativity and problem-solving are central to innovation management, market analysis, brand communication, entrepreneurship and customer-oriented value creation. However, despite the growing institutional emphasis on open science and creativity, there is still limited empirical evidence on how students' engagement with open science practices is associated with their perceived creativity and problem-solving capacity. This study addresses this gap by quantitatively examining open science practices as innovative educational tools in the context of marketing-oriented higher education.

1. LITERATURE REVIEW AND HYPOTHESES

The scientific landscape on open science, creativity and innovation-oriented education is grounded in the broader transformation of the knowledge economy, where learning, openness and creativity are increasingly treated as mutually reinforcing dimensions of social and economic development. Open science expands access to knowledge, research outputs and collaborative infrastructures, thereby creating conditions in which students can move beyond passive knowledge consumption towards active exploration, reuse and co-creation of ideas (Peters, 2010; Arza & Fressoli, 2018). The creative value of openness is also linked to the reduction of informational barriers, the stimulation of intellectual autonomy and the possibility of combining diverse knowledge sources in new ways (Frankenhuis & Nettle, 2018; Class, 2022). In educational settings, open learning formats and open science practices foster more flexible and participatory modes of knowledge acquisition, while empirical evidence from Ukrainian university students confirms the relevance of open science for youth creativity and academic self-development (Skrynnyk & Vasilyeva, 2020; Artyukhova et al., 2025).

Creativity and problem-solving in higher education are increasingly conceptualized as teachable and assessable competencies rather than purely individual talents. Innovative pedagogical formats, including STEAM education, design thinking, sustainability-oriented events and interdisciplinary learning environments, show that creativity emerges when students are encouraged to work with uncertainty, real-world problems and collaborative knowledge production (Bisognin et al., 2024; Chappell et al., 2025; Del-Valle Quintana et al., 2025). Entrepreneurial and design-thinking approaches further demonstrate that creative problem-solving is closely connected with the development of competencies needed for innovation, opportunity recognition and practical decision-making (Kaouache et al., 2024; Olortegui-Alcalde & Cordova-Buiza, 2026). At the same time, creativity studies require methodological caution because the measurement of creative outcomes may be statistically fragile and sensitive to task design, while psychologically safe environments remain important for nurturing creative performance (Arora et al., 2025; Torrents et al., 2026). The development of creativity also depends on psychological antecedents, human capital and innovation-oriented capacities, which makes open science relevant as a learning environment that can support both individual creative confidence and collective knowledge use (Alabood & Sulphey, 2026; Petrova & Pereira, 2024).

Marketing-oriented higher education provides a particularly relevant context for analyzing open science as an innovative educational tool, as contemporary marketing requires data literacy, communication skills, digital competence, evidence-based decision-making, and user-centered innovation. University communication policy and graduate feedback are increasingly used as instruments of educational marketing, which shows that students' perceptions and learning experiences are important components of institutional positioning and service improvement (Bliumska-Danko et al., 2025; Tirrel & Gellert, 2025). Digital transformation in education, gamification, artificial intelligence, and new technological learning formats reshape how students engage with information, collaboration, and creativity, creating additional demand for open, transparent, and reusable educational resources (Kovács et al., 2025; Sułkowski et al., 2026; Zimosz & Ober, 2025). The use of generative AI in teaching further strengthens the need to combine technological innovation with cognitive, ethical and academic-integrity considerations, while computational communication science highlights the importance of inclusive standards and transparent methodological practices (Lyeonov et al., 2026; Waldherr et al., 2024). The creative economy also faces new opportunities and risks from artificial intelligence, which makes open science-based learning relevant for preparing students to work responsibly with data, evidence and digital tools in marketing and communication practice (Schinello, 2025).

The relationship between open science, innovation transfer and university performance is also important for understanding how higher education can support creativity beyond the classroom. Models of science-business interaction show that universities can act as intermediaries between research, innovation and practical application, while digitalization and innovation transfer increasingly shape leadership trends in education (Artyukhov et al., 2023; Koibichuk et al., 2023). University-industry R&D collaboration is associated with innovation transfer and start-up performance, suggesting that open knowledge environments may strengthen the practical relevance of higher education and its contribution to innovation ecosystems (Kuzior et al., 2024a, 2024b). The philosophical and managerial understanding of innovation also requires practical wisdom, strategic evaluation, and institutional capacity, especially in research universities that must balance academic quality, openness to knowledge, and external engagement (Kuzior & Zozuľak, 2019; Zhylinska & Sitnitskiy, 2018). Open science and open access policies can also support innovation at the macro level, including patent activity, while science and technology parks demonstrate how internationalization and institutional life-cycle dynamics influence knowledge transfer environments (Lizińska et al., 2024; Sitnicki et al., 2025). Knowledge management is therefore a central mechanism through which open resources can be transformed into sustainable innovation, leadership capacity and educational value (Alemu, 2025).

The marketing and innovation management literature also shows that creativity-oriented education should be linked to entrepreneurship, market capabilities, and user-driven innovation. Marketing capability, product advantage, and perceptual product congruity influence firm performance, underscoring the need for marketing education to develop students' ability to transform knowledge into value propositions, market solutions, and innovation strategies (Siregar et al., 2026). Student entrepreneurial intention, social entrepreneurship and sustainable investment attitudes are shaped by knowledge, attitudes, risk perception and opportunity recognition, indicating that open science resources can support innovation-oriented mindsets in higher education (Czyżewska et al., 2025; Hossen et al., 2026; Kaouache et al., 2024). Start-ups, renewable-energy entrepreneurship and innovation proximity illustrate how knowledge access, networks, spatial interaction and investment conditions affect entrepreneurial ecosystems and

http://dx.doi.org/10.21511/im.22(2).2026.24

innovation outcomes (Dobrovolska et al., 2024; Zahidi et al., 2025). In creative industries, knowledge transfer and crowdsourcing stimulate innovation by connecting organizational learning with external participation. At the same time, digital tools such as drones, GIS and satellite technologies show how open and applied data infrastructures can support problem-solving in complex societal contexts (Hermawan et al., 2025; Szopik-Depczyńska et al., 2024; Mercer-Bey, 2025).

The effectiveness of open science as an educational tool also depends on institutional support, organizational climate and lecturer behavior. Higher education institutions may face barriers related to organizational silence, weak support systems and limited openness in communication, which can reduce students' willingness to use innovative learning resources (Kettaf et al., 2024). Lecturers' innovative work behavior, knowledge sharing and creative self-efficacy are important because students' engagement with open resources depends not only on access but also on guidance, motivation and pedagogical integration (Soediro et al., 2025; Suliati et al., 2025). Diversity, talent management, and human resource practices influence exploratory and exploitative innovation, demonstrating that both individual capabilities and organizational environments shape creativity (Baloch & Paoletti, 2025; Jeffers et al., 2025). Higher education systems must also balance academic standards, retention, dual education formats and students' future professional opportunities, which is especially relevant when open science is introduced as a practical tool for employability, lifelong learning and innovation-oriented skill development (Davlikanova, 2025; Green, 2025; Kołodziej & Kołodziej-Durnaś, 2024). Broader socio-economic challenges related to skills development and access to labor markets further reinforce the need for educational practices that connect open knowledge, creativity and professional readiness (Sigdel et al., 2026).

The reviewed literature suggests that open science can be understood not only as a research-policy principle but also as an educational infrastructure for creativity, collaboration, innovation and marketing-oriented problem-solving. Participatory science communities show that knowledge creation is increasingly network-based, while interdisciplinary complex systems thinking demonstrates the importance of combining diverse perspectives when addressing educational, technological and societal challenges (Zou & Yilmaz, 2010; Njegovanović, 2024). However, previous studies have more often examined open science, digital education, creativity, innovation transfer or entrepreneurship separately. In contrast, the specific association between students' use of open science practices and creativity-related perceptions in marketing-oriented higher education remains less developed. Therefore, the present study addresses this gap by empirically examining how open data, open educational resources, open scientific publications and barriers to adoption are associated with students' creativity, idea generation and problem-solving. The literature confirms that open science has strong potential as an innovative educational tool. However, its educational value depends on practical integration into curricula, lecturer support, student skills and the availability of accessible open resources.

This study aims to determine whether and how students' use of open science practices is associated with their perceptions of creativity, idea generation, and problem-solving in higher education with particular attention to open data, open educational resources, open scientific publications, and barriers to adoption as factors shaping innovation-oriented marketing education.

The empirical analysis was structured around three research hypotheses reflecting the assumed relationship between open science engagement and students' creativity-related perceptions. The hypotheses were formulated as follows:

H1: *More frequent use of open science elements is positively associated with students' perception that open science supports creativity, idea generation and problem-solving in academic tasks.*

H2: *Specific open science elements, particularly open data, open educational resources and open scientific publications, are positively associated with students' perception of the creative value of open science.*

H3: *Perceived barriers to using open science, such as lack of lecturer support, insufficient resources, lack of time, limited skills and re-*

stricted access to scientific events, are associated with students' perception of open science as a creativity-enhancing practice.

2. METHODOLOGY

2.1. Data collection

A quantitative cross-sectional survey design was applied. The survey collected data on students' frequency of use of open science practices, their assessment of various open science elements, and their perceived barriers to using open science in the learning process.

The survey was conducted from 20 September to 20 October 2024 using Google Forms. Participation was anonymous and voluntary. The survey covered students from Ukrainian higher education institutions across all Ukrainian regions, except temporarily occupied territories. The final sample included 2,250 respondents, representing Bachelor's, Master's and Ph.D. levels of study.

To justify the required sample size, Cochran's formula for large populations was used:

$$n_0 = \frac{Z^2 p(1-p)}{E^2}, \quad (1)$$

where n_0 is the required sample size, $Z = 1.96$ corresponds to a 95% confidence level, $p = 0.5$ is the assumed population proportion, and $E = 0.03$ is the margin of error. The calculated minimum sample size was 1,067 respondents. Therefore, the obtained sample of 2,250 respondents exceeded the minimum requirement.

The sample included 1,533 Bachelor's students, 401 Master's students and 316 Ph.D. students. Respondents represented different academic fields, including humanities and arts, social sciences, economics, life sciences, medicine, mathematics, chemistry, physics, engineering and environmental sciences. This disciplinary diversity enabled analysis of differences in open science engagement across academic backgrounds.

Before the main survey, the questionnaire was internally validated through pilot testing. The first pilot stage involved representatives of seven Ukrainian universities, with three student representatives from each university. The pilot testing focused on the clarity of the questions, the interpretation of response options and the time required to complete the questionnaire. Based on the feedback received, several questions were clarified. The revised questionnaire was then retested with another group of students from five additional universities, again involving three student representatives from each institution.

The questionnaire included variables describing students' educational backgrounds, the frequency of open science use, perceptions of open science, and barriers to its adoption. Survey responses were recorded using Likert-type scales. The main variables used in the analysis are presented in Table 1.

Table 1. Variables used in the study

Variable	Description
x1	Current level of study
x3	Frequency of using open science elements when completing academic tasks
x4	The perception that open science helps generate new ideas and approaches to solving academic tasks
x5	Open data
x6	Open code
x7	Open educational resources
x8	Open innovation
x9	Citizen science
x10	Open scientific publications
x11	Open scientific initiatives, including crowdsourcing projects
x12	Open peer review
x13	Other open science initiatives
x14	Lack of skills in working with open resources
x15	Lack of support from lecturers
x16	Insufficient number of open resources on the relevant topic
x17	Lack of time
x18	Lack of access to scientific events
x19	Other barriers

To ensure transparency between the survey instrument and the empirical variables, Table A3 in Appendix A provides a direct mapping between each coded variable used in the analysis and the corresponding questionnaire item. The empirical models did not use all questions from the broader questionnaire. They were based only on the selected block of items measuring the frequency of open science use, the perceived contribution

http://dx.doi.org/10.21511/im.22(2).2026.24

of specific open science elements to creativity and problem-solving, and perceived barriers to open science adoption. The empirical models did not use all questions from the broader questionnaire. They were based only on the selected block of items measuring the frequency of open science use, the perceived contribution of specific open science elements to creativity and problem-solving, and perceived barriers to open science adoption. Questions related to broader communication, creative society, and citizen science contexts were included to frame the survey conceptually, but not all were used in the correlation and regression models.

Survey responses were recorded using Likert-type ordered-response scales. The frequency of open science use (x3) was coded from 1 = never to 5 = very often. Agreement-based variables were coded as follows: 5 = strongly agree, 4 = agree, 3 = neither agree nor disagree, 2 = disagree, 1 = strongly disagree, and 0 = don't know. The "don't know" option was coded as 0 because it indicated the absence of a substantive evaluative position. This response could mean that respondents either lacked sufficient knowledge to agree or disagree, did not fully understand the question, or were not sufficiently familiar with the specific open science tool, practice, or term mentioned in the item. Therefore, this category was retained in the dataset as a separate response option and was interpreted cautiously in the analysis. The full distribution of responses is presented in Table A1 of Appendix A, while the questionnaire and the variable–question mapping table are provided in Appendix B.

Variables x5–x13 were used to assess which elements of open science students associate with creativity and expanded opportunities for creative thinking. Variables x14–x19 captured barriers that may limit the use of open science in the educational process. The dependent variables in the inferential analysis were the frequency of open science use (x3) and the perceived contribution of open science to creativity and problem-solving (x4), depending on the specific model.

2.2. Data analysis methods

The empirical analysis was conducted in RStudio and was designed to test three research hypotheses. *H1* was examined using Spearman's rank correlation coefficients between the frequency of open science use (x3) and creativity-related indicators of open science (x4–x13), as well as through an ordinal logistic regression model in which x3 was used as the dependent variable. *H2* was tested by analyzing the relationships between the overall perceived creative value of open science (x4) and individual open science elements (x5–x13), followed by an ordinal logistic regression model with x4 as the dependent variable. *H3* was examined using Spearman's rank correlations between perceived barriers to open science use (x14–x19) and x4, and through an ordinal logistic regression model assessing the effects of selected barriers on students' perceptions of the creative value of open science. Since the variables were measured using ordinal Likert-type scales, Spearman's rank correlation and ordinal logistic regression were considered appropriate methods for identifying statistically significant associations. The results were interpreted as associations rather than causal effects because of the cross-sectional survey design.

First, descriptive statistics were calculated to summarize the distribution of the main variables, including the minimum, first quartile, median, mean, third quartile and maximum values. These statistics were used to characterize respondents' level of study, frequency of open science use, perceived creativity-related value of open science practices and perceived barriers to their use. The full descriptive statistics are reported in Table A2, Appendix A.

Since most variables were measured using ordered Likert-type scales, Spearman's rank correlation coefficient was applied to examine monotonic associations between the variables. This method was used to assess the relationship between the frequency of open science use (x3) and perceived creativity-related effects of open science practices (x4–x13). It was also used to analyze the association between the overall perceived impact of open science on creativity (x4) and selected open science indicators, as well as between perceived barriers to open science use (x14–x19) and x4. The strength of correlations was interpreted according to the absolute value of Spearman's rho: very weak correlations below 0.20, weak correlations from 0.20 to below 0.40, and moderate correlations from 0.40 to below 0.60. Statistical significance was assessed using p-values.

To provide a visual overview of the relationships among the main variables, a Spearman rank correlation matrix was constructed for the frequency of open science use and creativity-related open science indicators. This matrix was used to identify the direction and relative strength of associations among x3 and variables x4–x13.

Ordinal logistic regression was then applied because the dependent variables were ordinal. Three proportional odds models were estimated. The first model examined the determinants of the frequency of open science use (x3), using selected creativity-related open science indicators as predictors. The second model assessed which open science elements were associated with the perceived contribution of open science to creativity and problem-solving (x4). The third model evaluated whether perceived barriers to open science use explained variation in x4. In each model, coefficients were interpreted as changes in the log odds of belonging to a higher response category, while odds ratios provided a clearer interpretation of the effect size. Positive coefficients indicated higher odds of stronger agreement or more frequent use, whereas negative coefficients indicated lower odds. For ordinal logistic regression models, p-values were calculated using the normal approximation based on the reported z-values.

The ordinal logistic regression models were used as exploratory association models rather than causal models. Since the variables were self-reported and collected within the same questionnaire using similar Likert-type response scales, the results should be interpreted as perception-based associations. The models identify which open science elements are more strongly associated with reported frequency of use and perceived creative value, but they do not establish causal effects. This approach is appropriate for the study's aim: to assess students' perceptions of open science as an innovative educational tool and to identify practical signals for marketing-oriented curriculum design.

Model specification was refined using the Akaike Information Criterion. Initial models included broader sets of theoretically relevant predictors, and variables with limited explanatory contribution were removed to obtain more parsimonious final models. Model fit was assessed using residual deviance and AIC values. The results were interpreted as statistical associations rather than causal effects, given the survey's cross-sectional design.

2.3. Ethical compliance

Ethical principles were followed throughout the study. Although the survey involved students from different Ukrainian higher education institutions, the research was coordinated by a team affiliated with Sumy State University, which was responsible for questionnaire design, data collection procedures, anonymous data storage, and overall research governance. Therefore, the questionnaire, data collection procedure, and research design were reviewed and approved by the Ethics Committee of Sumy State University, the coordinating institution. Other participating universities were involved only in disseminating the anonymous online questionnaire and did not collect personally identifiable information or conduct separate research procedures. Participation in the survey was voluntary, and informed consent was obtained from all respondents before they completed the questionnaire. No personally identifiable information was collected, which ensured anonymity and confidentiality. The study complied with ethical standards for survey-based research involving students in educational settings.

3. RESULTS

Descriptive response distributions are reported in Table A1, Appendix A, while summary statistics and inferential results are presented in the main body of the article.

Descriptive statistics were calculated to provide an initial overview of the dataset's structure and the distributions of the main variables. The analysis included the minimum, first quartile, median, mean, third quartile and maximum values for variables describing respondents' level of study, frequency of open science use, perceptions of the creativity-related value of open science, specific open science elements and perceived barriers to their use. The frequency of using open science elements (x3) and the general perception that open science supports idea generation and problem-solving (x4) both show relatively high median

http://dx.doi.org/10.21511/im.22(2).2026.24

values, indicating generally frequent engagement with open science and positive perceptions of its creative potential. Among the specific elements of open science, open educational resources (x7), open data (x5), open scientific publications (x10) and open innovation (x8) have the highest average values, suggesting that respondents most strongly recognize these elements as relevant to creativity. The descriptive statistics for perceived barriers show that insufficient open resources on a specific topic (x16), lack of time (x17) and lack of skills in working with open resources (x14) were among the more visible constraints. The full descriptive statistics are presented in Table A2, Appendix A.

3.1. Frequency of open science use and assessment of open science practices' contribution to creativity

Table 2 reports Spearman's rank correlation coefficients between the frequency of open science use and respondents' assessments of how different open science practices contribute to creativity. The results show positive, statistically significant associations for all analyzed indicators, indicating that more frequent engagement with open science is generally associated with stronger perceptions of its role in enhancing creativity.

The strongest association is observed for the generally perceived impact of open science on creativity (x4; $\rho = 0.498$, $p < 0.001$), which indicates a moderate positive relationship. This suggests that respondents who use open science more frequently are more likely to evaluate its general contribution to creative thinking positively. Among specific open science components, the highest correlations are found for open data (x5; $\rho = 0.295$), open educational resources (x7; $\rho = 0.260$), and open scientific publications (x10; $\rho = 0.240$). Although these relationships are relatively weak, they suggest that access to data, learning materials, and scientific publications may be particularly relevant for supporting idea generation and creative academic work.

Lower correlations are observed for open code (x6; $\rho = 0.132$), citizen science (x9; $\rho = 0.118$), open peer review (x12; $\rho = 0.148$), crowdsourcing initiatives (x11; $\rho = 0.185$), and other open initiatives (x13; $\rho = 0.110$). These findings suggest that respondents may recognize such practices less directly as sources of creativity, or that their role is more context-specific. However, all coefficients are statistically significant at $p < 0.001$, confirming that the observed relationships are unlikely to be random. The results support the assumption that the frequency of open science use is positively related to perceptions of creativity development. However, the strength of this relationship differs across individual open science practices.

Figure 1 presents the Spearman rank correlation matrix for the frequency of open science use (x3) and the indicators measuring the perceived creativity-related effects of open science practices (x4-x13). The matrix shows that all relationships are positive, indicating that more frequent use of open science is generally associated with more favorable perceptions of its contribution to creativity and idea generation.

Table 2. Spearman's rank correlations between the frequency of open science use and perceived creativity-related effects of open resources

Source: Authors' calculations based on survey data using RStudio.

Variable	Indicator	Spearman's ρ	p-value	Correlation strength
x4	Overall impact of open science on creativity	0.498	< 0.001	Moderate
x5	Open data	0.295	< 0.001	Weak
x6	Open code	0.132	< 0.001	Very weak
x7	Open educational resources	0.260	< 0.001	Weak
x8	Open innovations	0.202	< 0.001	Weak
x9	Citizen science	0.118	< 0.001	Very weak
x10	Open scientific publications	0.240	< 0.001	Weak
x11	Crowdsourcing initiatives	0.185	< 0.001	Very weak
x12	Open peer review	0.148	< 0.001	Very weak
x13	Other open initiatives	0.110	< 0.001	Very weak

Source: Authors' calculations based on survey data using RStudio.

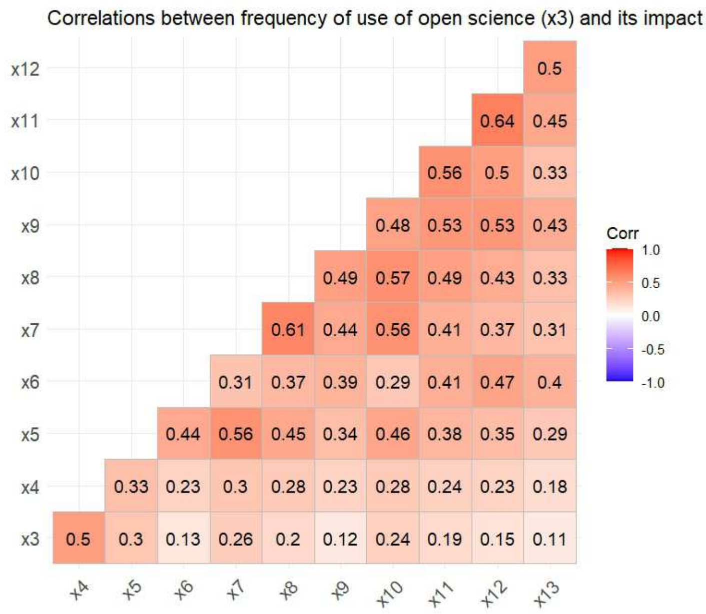

Figure 1. Spearman rank correlation matrix for the frequency of open science use and creativity-related open science indicators

The strongest association with the frequency of open science use is observed for the overall perceived impact of open science on creativity (x4; ρ = 0.50). This confirms that respondents who engage more with open science tend to evaluate its general creative value more positively. Among the specific open science components, the highest correlations with x3 are observed for open data (x5; ρ = 0.30), open educational resources (x7; ρ = 0.26), and open scientific publications (x10; ρ = 0.24). These results suggest that access to data, educational materials, and scientific publications may be the most visible channels through which open science supports creativity.

At the same time, weaker correlations are found for open code (x6; ρ = 0.13), citizen science (x9; ρ = 0.12), open peer review (x12; ρ = 0.15), and other open initiatives (x13; ρ = 0.11). This may indicate that these forms of open science are either less frequently used by respondents or less directly associated with creative outcomes in their academic experience. The matrix also reveals relatively strong intercorrelations among several creativity-related indicators, particularly between open educational resources, open peer review, open scientific publications, and crowdsourcing initiatives. This suggests that different open science practices may reinforce one another in shaping a broader environment favorable to creativity.

Figure 1 supports the conclusion that open science use is positively related to perceived creativity development. However, the strength of this relationship varies across open science practices, and the results should be interpreted as associations rather than causal effects.

The next stage of the analysis involved estimating an ordinal logistic regression model (Table 3) to identify which perceived creativity-related effects of open science explain the frequency of open science use. Since the dependent variable, x3, was measured on an ordinal Likert scale, the proportional odds ordinal logistic regression model was applied. The model examines whether respondents who assess specific open science practices as more useful for creativity and problem-solving are more likely to report greater frequency of open science use.

The final model was selected through an iterative procedure. The initial specification included all creativity-related indicators from x4 to x13. Variables with limited explanatory contribution were gradually removed, while model adequacy was assessed using the Akaike Information Criterion (AIC). The final specification retained x4, x5, x6, x7, x9, x10, and x11 as predictors of the ordinal dependent variable x3.

http://dx.doi.org/10.21511/im.22(2).2026.24

Table 3. Ordinal logistic regression results for the factors associated with reported open science use frequency

Source: Authors' calculations based on survey data using RStudio.

Predictor	Description	Coefficient	Std. error	z-value	p-value	Odds ratio
x4	Overall impact of open science on creativity	1.236	0.057	21.847	< 0.001	3.440
x5	Open data	0.232	0.062	3.712	< 0.001	1.261
x6	Open code	–0.087	0.039	–2.218	0.027	0.916
x7	Open educational resources	0.211	0.072	2.931	0.003	1.235
x9	Citizen science	–0.159	0.049	–3.278	0.001	0.853
x10	Open scientific publications	0.106	0.060	1.773	0.076	1.111
x11	Crowdsourcing initiatives	0.077	0.046	1.672	0.095	1.080
Model threshold		**Estimate**	**Std. error**		**z-value**	
1|2		0.446	0.351		1.272	
2|3		2.904	0.297		9.782	
3|4		5.593	0.310		18.022	
4|5		8.035	0.332		24.232	
Model fit indicator		**Value**				
Residual deviance		4,750.705				
AIC		4,772.705				

Note: The dependent variable is x3, which measures the frequency of open science use. Positive coefficients indicate a higher probability of belonging to a higher frequency category of open science use. Odds ratios above 1 indicate an increase in the odds of more frequent use, while odds ratios below 1 indicate a decrease. P-values were calculated using the normal approximation based on the reported z-values.

The results show that the strongest predictor of open science use frequency is the overall perception that open science contributes to creativity and idea generation. The coefficient for x4 is positive and highly statistically significant ($\beta = 1.236$, $p < 0.001$), while the odds ratio equals 3.440. This means that a one-unit increase in the perceived overall creative value of open science is associated with more than a threefold increase in the odds of reporting higher open science use frequency.

Among the specific open science practices, students' positive evaluations of open data (x5) and open educational resources (x7) are also positively and statistically significantly associated with reported frequency of open science use. The odds ratio for open data is 1.261, indicating that respondents who perceive open data as useful for creativity are more likely to use open science frequently. Similarly, the odds ratio for open educational resources is 1.235, suggesting that access to open learning materials is positively associated with more regular engagement with open science. These findings suggest that practical, easily accessible open resources are among the open science elements most closely associated with students' reported engagement, although the cross-sectional, self-reported nature of the data does not allow causal conclusions.

The coefficients for open code (x6) and citizen science (x9) are negative and statistically significant. This means that higher perceived usefulness of these elements is associated with slightly lower odds of more frequent open science use. In the case of open code, the odds ratio is 0.916; for citizen science, it is 0.853. These results should be interpreted carefully. They may indicate that these forms of open science are more specialized, less familiar to respondents, or less directly integrated into their everyday educational and research practices.

Open scientific publications (x10) and crowdsourcing initiatives (x11) have positive but weaker effects. Their coefficients are only marginally significant at the 10% level, which means that their influence on the frequency of open science use is less robust than that of x4, x5, and x7. Therefore, although these practices may support open science engagement, their explanatory power in the model is comparatively limited.

The model thresholds represent the cut-off points between adjacent categories of the ordinal dependent variable. Their increasing values indicate that movement from lower to higher levels of open science use requires progressively stronger motivating factors. In practical terms, occasional use of open science may be relatively easy to achieve. In contrast, regular or very frequent use requires stronger perceived benefits, particularly the belief that open science enhances creativity, supports idea generation, and provides access to useful resources.

The ordinal logistic regression results suggest that the most important driver of frequent open science use is the belief that open science contributes to creativity. Open data and open educational resources also play a meaningful role, while the effects of open code, citizen science, open publications, and crowdsourcing are weaker or more context-dependent. These findings highlight the importance of integrating open data, open learning materials, and creativity-oriented open science practices into educational and research environments.

3.2. The overall perceived impact of open science on creativity

The relationship between the overall perceived impact of open science on creativity (x4) and the remaining variables was further examined using Spearman's rank correlation coefficients (Table 4). This analysis enables assessment of the strength and direction of monotonic associations between x4 and the frequency of open science use, as well as between x4 and specific open science practices. All coefficients are positive and statistically significant at $p < 0.001$, indicating that stronger agreement with the creative value of open science is associated with higher assessments of its individual components and with more frequent use of open science practices.

The strongest relationship is observed between x4 and the frequency of open science use (x3; $\rho = 0.498$). This moderate positive association suggests that respondents who use open science more frequently are also more likely to perceive it as beneficial for creativity and problem-solving. This result is consistent with the assumption that regular exposure to open science resources may strengthen users' awareness of their creative and educational value.

Among the specific open science components, the highest correlations with x4 are found for open data (x5; $\rho = 0.327$), open educational resources (x7; $\rho = 0.300$), open scientific publications (x10; $\rho = 0.282$), and open innovations (x8; $\rho = 0.280$). Although these relationships are weak in magnitude, they indicate that access to data, educational content, publications, and innovation-related resources is positively associated with the perceived creative potential of open science.

Weaker associations are found for crowdsourcing initiatives (x11; $\rho = 0.237$), open code (x6; $\rho = 0.233$), citizen science (x9; $\rho = 0.228$), open peer review (x12; $\rho = 0.227$), and other open initiatives

Table 4. Spearman's rank correlations between the overall perceived impact of open science on creativity and selected open science indicators

Source: Authors' calculations based on survey data using RStudio.

Variable	Indicator	Spearman's ρ	p-value	Correlation strength
x3	Frequency of open science use	0.498	< 0.001	Moderate
x5	Open data	0.327	< 0.001	Weak
x6	Open code	0.233	< 0.001	Weak
x7	Open educational resources	0.300	< 0.001	Weak
x8	Open innovations	0.280	< 0.001	Weak
x9	Citizen science	0.228	< 0.001	Weak
x10	Open scientific publications	0.282	< 0.001	Weak
x11	Crowdsourcing initiatives	0.237	< 0.001	Weak
x12	Open peer review	0.227	< 0.001	Weak
x13	Other open initiatives	0.179	< 0.001	Very weak

Note: ρ denotes Spearman's rank correlation coefficient. Correlation strength was interpreted as follows: very weak, $|\rho| < 0.20$; weak, $0.20 \le |\rho| < 0.40$; moderate, $0.40 \le |\rho| < 0.60$.

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(x13; ρ = 0.179). These results suggest that these practices are also related to perceptions of open science's creative value, but their role appears to be less pronounced. This may reflect their more specialized character, lower visibility among respondents, or weaker integration into everyday educational and research activities.

The results show that the perceived impact of open science on creativity is most closely associated with the frequency of open science use. Specific resources, such as open data, open educational resources, and open scientific publications, also contribute to this perception, though their associations are weaker. Therefore, the findings confirm that open science is positively associated with creativity-related perceptions, but the strength of this association varies across individual open science practices.

The ordinal logistic regression model was estimated to examine which open science components are associated with respondents' perception that open science supports the generation of new ideas and approaches to solving educational tasks. The dependent variable was x4, and selected open-science elements were included as predictors. Since x4 was measured on an ordinal Likert scale, ordinal logistic regression was used to model ordered response categories. The results in Table 5 indicate that all selected predictors are positively associated with the perceived creative value of open science. The strongest association is observed for open data (x5), which has the highest coefficient and odds ratio ($\beta = 0.529$; OR = 1.697; $p < 0.001$). This means that a one-unit increase in the perceived usefulness of open data is associated with a 69.7% increase in the odds of reporting a higher level of agreement that open science supports creativity and problem-solving.

Open educational resources (x7) also show a positive and statistically significant relationship with x4 ($\beta = 0.266$; OR = 1.305; $p < 0.001$). This suggests that respondents who value open educational resources are more likely to perceive open science as a tool for generating new ideas. Open scientific publications (x10) have a smaller but significant positive effect ($\beta = 0.158$; OR = 1.172; $p = 0.006$), indicating that access to scientific literature also contributes to the perceived creative benefits of open science.

Citizen science (x9) and open peer review (x12) demonstrate weaker but still statistically significant positive associations. Their odds ratios are

Table 5. Ordinal logistic regression results for open science elements associated with the perceived creative value of open science

Source: Authors' calculations based on survey data using RStudio.

Predictor	Indicator	Coefficient	Std. error	z-value	p-value	Odds ratio
x5	Open data	0.529	0.060	8.783	< 0.001	1.697
x7	Open educational resources	0.266	0.072	3.677	< 0.001	1.305
x9	Citizen science	0.100	0.046	2.148	0.032	1.105
x10	Open scientific publications	0.158	0.058	2.752	0.006	1.172
x12	Open peer review	0.090	0.041	2.194	0.028	1.094
Model threshold		**Estimate**	**Std. error**		**z-value**	
0|1		0.501	0.296		1.696	
1|2		0.722	0.289		2.496	
2|3		1.769	0.275		6.437	
3|4		4.029	0.283		14.222	
4|5		6.534	0.302		21.649	
Model fit indicator		**Value**				
Residual deviance		5,073.908				
AIC		5,093.908				

Note: The dependent variable is x4, which measures the perceived contribution of open science to creativity and the generation of new ideas. Positive coefficients indicate a higher probability of belonging to a higher agreement category. Odds ratios above 1 indicate increased odds of stronger agreement. P-values were calculated using the normal approximation based on the reported z-values.

close to 1, indicating a comparatively limited practical effect. Nevertheless, their significance suggests that participatory and evaluative dimensions of open science may still contribute to respondents' perceptions of creativity, although less strongly than open data or open educational resources.

The model thresholds represent the cut-off points between adjacent response categories of the dependent variable. Their increasing values indicate that movement towards stronger agreement with the statement that open science supports creativity requires progressively stronger explanatory factors. In other words, reaching the highest levels of perceived creative value is more demanding than moving between lower response categories.

The findings suggest that open data is the most important predictor of respondents' positive perception of open science as a creativity-enhancing practice. Open educational resources and open scientific publications also play a meaningful role, while citizen science and open peer review have weaker but statistically significant associations. These results highlight the importance of improving access to open data, educational materials, and scientific publications to strengthen the creative and problem-solving potential of open science in educational settings.

3.3. The role of perceived barriers to open science

The role of perceived barriers to open science was examined using Spearman rank correlations and ordinal logistic regression. First, Spearman's rank correlation coefficients were calculated to assess the direction and strength of the associations between selected barriers to open science and students' perceptions of whether open science helps generate new ideas and approaches to solving educational tasks. The results presented in Table 6 indicate that the relationships between barriers to open science and the perceived creative value of open science are generally very weak. The strongest association is observed for the lack of sufficient open resources on a specific topic (x16; $\rho = 0.095$, $p < 0.001$), although the magnitude of this relationship remains very small. This suggests that students who report difficulties in finding relevant open resources may still recognize the potential of open science to support creativity and problem-solving.

The results presented in Table 6 indicate that the relationships between barriers to open science and the perceived creative value of open science are generally very weak. The strongest association is observed for the lack of sufficient open resources on a specific topic (x16; $\rho = 0.095$, $p < 0.001$), although the magnitude of this relationship remains very small. This suggests that students who report difficulties in finding relevant open resources may still recognize the potential of open science to support creativity and problem-solving.

Weak but statistically significant positive associations are also observed for lack of access to scientific events (x18; $\rho = 0.069$, $p = 0.001$), other barriers (x19; $\rho = 0.064$, $p = 0.002$), x17 ($\rho = 0.046$, $p = 0.031$), and x14 ($\rho = 0.045$, $p = 0.031$). However, these coefficients are close to zero, indicating limited practical significance. In contrast, lack of instructor support (x15) is not statistically significant ($\rho = 0.009$, $p = 0.679$), indicating no meaningful bivariate association with students' perceptions of the creative value of open science.

Table 6. Spearman's rank correlations between barriers to open science and the perceived creative value of open science

Source: Authors' calculations based on survey data using RStudio.

Variable	Barrier indicator	Spearman's ρ	p-value	Correlation strength
x14	Barrier related to open science use	0.045	0.031	Very weak
x15	Lack of support from instructors	0.009	0.679	Not significant
x16	Lack of sufficient open resources on a specific topic	0.095	< 0.001	Very weak
x17	Barrier related to open science use	0.046	0.031	Very weak
x18	Lack of access to scientific events	0.069	0.001	Very weak
x19	Other barriers	0.064	0.002	Very weak

Note: ρ denotes Spearman's rank correlation coefficient.

http://dx.doi.org/10.21511/im.22(2).2026.24

The correlation results suggest that perceived barriers are only weakly connected with students' views on open science as a source of creativity. Therefore, these barriers should not be interpreted as strong determinants of perceptions, although some of them may still reflect contextual difficulties in the practical use of open science resources.

The next stage of the analysis involved estimating an ordinal logistic regression model to assess whether selected barriers explain variation in students' perceptions of the creative value of open science. The dependent variable was x4, which measures agreement with the statement that open science helps generate new ideas and approaches for solving educational tasks. The results in Table 7 show that a lack of instructor support (x15) has a negative, statistically significant effect on students' perceptions of the creative value of open science ($\beta = -0.092$, $p = 0.015$). The odds ratio of 0.912 indicates that a one-unit increase in this barrier reduces the odds of reporting a higher level of agreement that open science supports creativity by approximately 8.8%. This finding suggests that insufficient guidance or encouragement from educators may weaken students' recognition of the creative potential of open science.

The lack of sufficient open resources on a specific topic (x16) has a positive and statistically significant coefficient ($\beta = 0.090$, $p = 0.033$). Although the effect is small, the odds ratio of 1.094 suggests that students who identify this barrier are slightly more likely to recognize the creative value of open science. This result may indicate that students who actively seek open resources are more aware of both their benefits and limitations.

The lack of access to scientific events (x18) and other barriers (x19) show positive effects, though only marginally significant. Their odds ratios are close to 1, indicating limited practical influence. Therefore, these variables should be interpreted cautiously, as their contribution to explaining students' perceptions is weaker than that of instructor support and the availability of relevant open resources.

The threshold estimates represent the cut-off points between adjacent response categories of the dependent variable. Their increasing values indicate the ordered structure of the response scale and show that movement towards stronger agreement with the creative value of open science requires stronger explanatory conditions.

The findings suggest that barriers to open science have a relatively limited but still relevant role in shaping students' perceptions. The most important result is that insufficient instructor support

Table 7. Ordinal logistic regression results for the effect of open science barriers on the perceived creative value of open science

Source: Authors' calculations based on survey data using RStudio.

Predictor	Barrier indicator	Coefficient	Std. error	z-value	p-value	Odds ratio
x15	Lack of support from instructors	–0.092	0.038	–2.443	0.015	0.912
x16	Lack of sufficient open resources on a specific topic	0.090	0.042	2.131	0.033	1.094
x18	Lack of access to scientific events	0.071	0.042	1.700	0.089	1.073
x19	Other barriers	0.051	0.028	1.835	0.067	1.052

Model threshold	Estimate	Std. error	z-value
0|1	–3.628	0.216	–16.819
1|2	–3.433	0.205	–16.755
2|3	–2.492	0.171	–14.585
3|4	–0.471	0.151	–3.128
4|5	1.811	0.156	11.635

Model fit indicator	Value
Residual deviance	5398.931
AIC	5416.931

Note: The dependent variable is x4, which measures the perceived contribution of open science to creativity and the generation of new ideas. Positive coefficients indicate higher odds of belonging to a higher agreement category, while negative coefficients indicate lower odds. P-values were calculated using the normal approximation based on the reported z-values.

may reduce students' recognition of open science as a practice that enhances creativity. At the same time, difficulties in finding relevant open resources may reflect greater engagement with open science rather than rejection of its value. This highlights the importance of academic guidance, better resource curation, and institutional support in strengthening the role of open science in creativity and problem-solving.

The hypothesis testing results provide empirical support for all three research hypotheses, although the strength of support differs across them. *H1* is supported, as the frequency of open science use is positively and statistically significantly associated with students' perception that open science supports creativity, idea generation and problem-solving, with the strongest relationship observed for the overall perceived creative value of open science. *H2* is also supported, since specific open science elements, particularly open data, open educational resources and open scientific publications, show positive and statistically significant associations with the perceived creative value of open science. H3 is partially supported: perceived barriers are associated with students' perceptions of open science, but their effects are generally weak. The most important barrier-related finding is that the lack of instructor support has a negative, statistically significant effect on the perceived creative value of open science, whereas insufficient open resources show a small positive association, likely reflecting greater awareness among students who actively seek such resources. Therefore, the findings confirm the general relevance of open science as a creativity-enhancing educational tool, while also showing that its effectiveness depends on access to practical resources and lecturer support.

4. DISCUSSION

The findings confirm the central assumption that open science engagement is positively associated with students' perceptions of creativity, idea generation and problem-solving in marketing-oriented higher education. The moderate correlation between the frequency of open science use and the overall perceived creative value of open science, together with the ordinal regression result showing that this perception increases the odds of more frequent open science use more than threefold, supports the view that openness in knowledge access can stimulate more active and creative learning behaviour. This result is consistent with the broader literature, which interprets openness, learning, and creativity as interrelated components of the knowledge economy and argues that open science can reduce informational barriers, increase intellectual autonomy, and expand opportunities for knowledge recombination (Peters, 2010; Arza & Fressoli, 2018; Frankenhuis & Nettle, 2018). It also supports previous evidence from students at Ukrainian universities showing that open science practices are relevant for youth creativity and academic self-development (Artyukhova et al., 2025). In the context of marketing-oriented education, this relationship is particularly important because marketing students need to generate ideas, interpret evidence, work with data and transform knowledge into value propositions, communication strategies and innovation-oriented solutions.

The empirical results on the role of open data, open educational resources, and open scientific publications are also consistent with earlier studies on innovation-oriented learning and digital transformation in higher education. Open data had the strongest association with the perceived creative value of open science in the ordinal regression model. At the same time, open educational resources and open scientific publications also increased the likelihood of a stronger agreement that open science supports creativity and problem-solving. These findings align with the literature, which shows that creativity develops when students work on real-world problems, use evidence, engage with interdisciplinary knowledge, and collaborate (Bisognin et al., 2024; Chappell et al., 2025; Del-Valle Quintana et al., 2025). They also complement research on digitalization, gamification, generative AI and computational communication science, which highlights the growing need for transparent, reusable and methodologically sound educational resources in modern learning environments (Kovács et al., 2025; Lyeonov et al., 2026; Waldherr et al., 2024). From the perspective of marketing education, these results suggest that open data and open resources are not only valuable learning materials but also practical tools for market analysis, consumer research, digital communication, and evidence-based innovation management.

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At the same time, the weaker or more ambiguous effects of some open science components and barriers suggest that access alone is insufficient to transform open science into a creativity-enhancing educational practice. The negative coefficients for open code and citizen science in the model explaining frequency of open science use may indicate that these practices are more specialized, less familiar or less integrated into students' everyday academic tasks. This interpretation is consistent with studies emphasizing that creative and innovation-oriented learning depends not only on resources but also on organizational climate, lecturer support, knowledge sharing and pedagogical guidance (Kettaf et al., 2024; Soediro et al., 2025; Suliati et al., 2025). The finding that lack of instructor support negatively affects students' perception of open science's creative value further reinforces this point. It suggests that the educational impact of open science depends on how effectively lecturers embed open data, publications, peer review, citizen science and collaborative tools into coursework, project-based learning and marketing problem-solving tasks. Therefore, the results extend the literature by showing that open science has clear potential as an innovative educational tool. However, its effectiveness in marketing-oriented higher education requires structured pedagogical integration, resource curation and institutional support.

The study has several limitations that should be considered when interpreting the results. First, the research is based on a cross-sectional survey, which means that the identified relationships between open science use, creativity-related perceptions and barriers should be interpreted as statistical associations rather than causal effects. Second, the data rely on self-reported responses, so students' assessments may reflect subjective perceptions, personal experience or social desirability bias. Third, although the sample is large and covers students from Ukrainian higher education institutions, the findings may not be fully generalizable to other national or institutional contexts. Although the study is positioned within marketing-oriented higher education, the questionnaire did not include a separate block on branding, consumer behavior, market analysis or digital marketing tasks. Thus, the findings should be interpreted as evidence on open science practices supporting marketing-relevant competencies, not as direct evidence on marketing education itself. In addition, all variables were self-reported and measured through similar Likert-type scales, which may create common-method bias. Therefore, the results show associations rather than causal effects. Future research should include marketing-specific variables and use behavioral, experimental or longitudinal data. Future research should therefore apply longitudinal or experimental designs to examine whether systematic integration of open science tools directly improves students' creativity, idea generation and problem-solving skills. Comparative studies across countries, universities and fields of study would also be valuable, especially in marketing-oriented programs, where open data, open educational resources and open scientific publications could be tested as practical tools for innovation management, market analysis, consumer research and creative communication. Besides, future studies could combine quantitative modelling with qualitative interviews or focus groups to better understand how students and lecturers actually use open science practices in educational settings and what institutional support is needed to increase their effectiveness.

CONCLUSIONS

This study aimed to assess how open science practices function as innovative educational tools for strengthening creativity, idea generation and problem-solving in marketing-oriented higher education. Particular attention was paid to the frequency of students' use of open science, the perceived creative value of specific open science elements, and the barriers that may limit their integration into the learning process.

The empirical analysis was based on a cross-sectional survey of 2,250 students from Ukrainian higher education institutions, including Bachelor's, Master's and Ph.D. students. The data were analyzed in RStudio using descriptive statistics, Spearman's rank correlation coefficients, a Spearman correlation matrix and ordinal logistic regression models, which were appropriate for the ordinal Likert-type structure of the survey data.

The results confirm that the frequency of open science use is positively associated with students' perception of its contribution to creativity and problem-solving, with the strongest correlation observed between open science use and the overall perceived creative impact of open science ($\rho = 0.498$; $p < 0.001$). Among specific open science elements, the strongest correlations with the frequency of open science use were found for open data ($\rho = 0.295$), open educational resources ($\rho = 0.260$) and open scientific publications ($\rho = 0.240$). The ordinal logistic regression model showed that the overall perceived creative value of open science was the strongest predictor of more frequent open science use ($\beta = 1.236$; OR = 3.440; $p < 0.001$), while open data (OR = 1.261) and open educational resources (OR = 1.235) also increased the odds of more frequent engagement. When the perceived creative value of open science was used as the dependent variable, open data had the strongest positive effect ($\beta = 0.529$; OR = 1.697; $p < 0.001$), followed by open educational resources (OR = 1.305) and open scientific publications (OR = 1.172). The analysis of barriers showed that their effects were generally weak; however, lack of support from instructors had a negative and statistically significant effect on the perceived creative value of open science ($\beta = -0.092$; OR = 0.912; $p = 0.015$), while insufficient open resources on a specific topic showed a small positive association ($\beta = 0.090$; OR = 1.094; $p = 0.033$).

The findings suggest that universities should integrate open science more systematically into marketing-oriented higher education as a practical tool for developing creativity, analytical thinking and innovation-oriented problem-solving. Educational policy at the institutional level should prioritize access to open data, open educational resources and open scientific publications, as these elements showed the strongest associations with students' creative perceptions and engagement. Marketing programs should include assignments based on open datasets, evidence-based case studies, open research materials and collaborative digital platforms, enabling students to apply scientific knowledge to market analysis, consumer behavior, branding, communication and innovation management tasks. At the same time, universities should reduce barriers by providing lecturer training, student guidance, curated repositories of open resources and structured support for using open science in coursework and research projects. Such measures can strengthen the role of open science as an innovative educational tool and improve students' readiness for data-driven, creative and socially responsible marketing practice.

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http://dx.doi.org/10.21511/im.22(2).2026.24

ACKNOWLEDGMENTS

This research was funded by an EU grant "Immersive Marketing in Education: Model Testing and Consumers' Behavior" under the project No. 09I03-03-V04-00522/2024/VA, by the Cultural and Educational Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic under the project "Innovative business models in relation to Generation Z consumer behavior towards economic decarbonization activities" under project No. KEGA 026EU-4/2026 and by the Ministry of Education and Science of Ukraine "Modeling and forecasting of socioeconomic consequences of higher education and science reforms in wartime" under the project No. 0124U000545.

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APPENDIX A

Table A1. The distribution of responses

Source: Authors' calculations based on survey data using RStudio.

Variables	Characteristics						Summary
	Bachelor		Master		Ph.D. student		Total
x1	1,533		401		316		2,250
Variables	**Never**	**Seldom**	**Sometimes**	**Often**	**Very often**		**Total**
x3	18	100	580	1018	534		2,250
Variables	**Never**	**Seldom**	**Sometimes**	**Often**	**Always**	**I do not know**	**Total**
x4	8	68	528	1145	463	38	2,250
Variable	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	**I do not know**	**Total**
x5	19	10	209	1,438	549	25	2,250
x6	48	19	620	715	727	121	2,250
x7	16	6	174	1,524	513	17	2,250
x8	22	12	238	1,351	597	30	2,250
x9	43	20	498	956	679	54	2,250
x10	20	12	239	1,377	571	31	2,250
x11	30	21	413	1,045	661	80	2,250
x12	62	18	511	872	691	96	2,250
x13	34	17	673	742	520	264	2,250
x14	140	143	515	741	672	39	2,250
x15	250	267	718	420	541	54	2,250
x16	121	102	429	857	703	38	2,250
x17	123	102	525	833	628	39	2,250
x18	178	150	690	582	599	51	2,250
x19	59	66	964	450	327	384	2,250

Note: Variables are defined in Table 1.

Table A2. Descriptive statistics for the study variables

Source: Authors' calculations based on survey data using RStudio.

Variable	Min	1st qu.	Median	Mean	3rd u.	Max
x1	1.000	1.000	1.000	1.459	2.000	3.000
x3	1.000	3.000	4.000	3.867	4.000	5.000
x4	0.000	3.000	4.000	3.832	4.000	5.000
x5	0.000	4.000	5.000	4.472	5.000	5.000
x6	0.000	3.000	4.000	3.759	5.000	5.000
x7	0.000	4.000	5.000	4.548	5.000	5.000
x8	0.000	4.000	5.000	4.406	5.000	5.000
x9	0.000	3.000	4.000	4.043	5.000	5.000
x10	0.000	4.000	5.000	4.417	5.000	5.000
x11	0.000	4.000	4.000	4.084	5.000	5.000
x12	0.000	3.000	4.000	3.911	5.000	5.000
x13	0.000	3.000	4.000	3.508	5.000	5.000
x14	0.000	3.000	4.000	3.716	5.000	5.000
x15	0.000	2.000	3.000	3.193	4.000	5.000
x16	0.000	3.000	4.000	3.879	5.000	5.000
x17	0.000	3.000	4.000	3.822	5.000	5.000
x18	0.000	3.000	4.000	3.503	5.000	5.000
x19	0.000	3.000	3.000	2.948	4.000	5.000

Note: Variables are defined in Table 1.

http://dx.doi.org/10.21511/im.22(2).2026.24

Table A3. Mapping between empirical variables and questionnaire items

Variable	Empirical meaning	Corresponding questionnaire item
x1	Current level of study	What level of education are you currently pursuing?
x3	Frequency of using open science elements when completing academic tasks	How often do you use open science elements when completing academic tasks?
x4	Perception that open science helps generate new ideas and approaches to solving academic tasks	Do you agree that open science helps generate new ideas and approaches to solving academic tasks?
x5	Open data	Open data as an element supporting creativity and problem-solving
x6	Open code	Open code as an element supporting creativity and problem-solving
x7	Open educational resources	Open educational resources as an element supporting creativity and problem-solving
x8	Open innovation	Open innovation as an element supporting creativity and problem-solving
x9	Citizen science	Citizen science as an element supporting creativity and problem-solving
x10	Open scientific publications	Open scientific publications as an element supporting creativity and problem-solving
x11	Open scientific initiatives, including crowdsourcing projects	Open scientific initiatives, including crowdsourcing projects, as elements supporting creativity and problem-solving
x12	Open peer review	Open peer review as an element supporting creativity and problem-solving
x13	Other open science initiatives	Other open science initiatives as elements supporting creativity and problem-solving
x14	Lack of skills in working with open resources	Lack of skills in working with open resources as a barrier to using open science
x15	Lack of support from lecturers	Lack of support from lecturers as a barrier to using open science
x16	Insufficient number of open resources on the relevant topic	Insufficient number of open resources on the relevant topic as a barrier to using open science
x17	Lack of time	Lack of time as a barrier to using open science
x18	Lack of access to scientific events	Lack of access to scientific events as a barrier to using open science
x19	Other barriers	Other barriers to using open science

APPENDIX B

1. What is your current status?

☐ Student
☐ Aspiring professional
☐ Other (please specify)

2. What is your area of study or field of interest?

☐ HUM: Humanities & Arts
☐ SOC: Social Sciences (including Law)
☐ ECO: Economic Sciences
☐ LIF: Life Sciences
☐ MED: Medicine (incl. Veterinary Medicine)
☐ MAT: Mathematics
☐ CHE: Chemistry
☐ PHY: Physics
☐ ENG: Information Sciences and Engineering
☐ ENV: Environment and Geosciences

3. How familiar are you with the concept of open and citizen science?

☐ Very familiar
☐ Somewhat familiar
☐ Not familiar at all

4. **What level of education are you currently pursuing?**

☐ Undergraduate
☐ Graduate
☐ Other (please specify)

5. **Do you think open and citizen science can improve communication and collaboration within the creative society?**

☐ Strongly agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly disagree

6. **What areas of communication do you think could benefit the most from open and citizen science?**

☐ Public awareness and education
☐ Science journalism and media reporting
☐ Digital storytelling and multimedia content
☐ Collaborative research and interdisciplinary dialogue
☐ Social media engagement and community outreach
☐ Policy-making and advocacy communication
☐ Creative writing and artistic expression
☐ Environmental communication and activism
☐ Other (please specify): _____________

7. **What areas of creative communication do you think could benefit the most from open and citizen science?** (Select all that apply)

☐ Art and visual storytelling (e.g., digital art, exhibitions)
☐ Film and documentary production
☐ Creative writing (e.g., fiction, non-fiction, poetry)
☐ Interactive media (e.g., games, virtual reality, augmented reality)
☐ Public installations and performance art
☐ Design and innovation (e.g., user experience, graphic design)
☐ Music and sound design
☐ Cross-disciplinary projects (e.g., combining science, technology, and art)
☐ Social media and digital campaigns
☐ Other (please specify): _____________

8. **How important is it for the creative society (e.g., artists, writers, communicators) to engage with science and research?**

☐ Extremely important
☐ Very important
☐ Somewhat important
☐ Not important

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9. **What do you think are the major opportunities for creative professionals in engaging with open and citizen science?** (Select all that apply)

☐ Access to new knowledge
☐ Collaboration with scientists
☐ Public engagement
☐ Creation of innovative content
☐ Solving real-world problems
☐ Other (please specify)

10. **In what ways could citizen science empower communities and contribute to creative projects?**

☐ Enhancing community engagement and participation in local projects
☐ Providing access to scientific data for storytelling or art
☐ Creating collaborative platforms between scientists, artists, and the public
☐ Raising awareness of social or environmental issues through creative expression
☐ Encouraging diverse perspectives and voices in creative works
☐ Fostering a sense of ownership and activism through art and science collaboration
☐ Other (please specify)

11. **Have you participated in any citizen science projects before?**

☐ Yes
☐ No
If yes, please briefly describe your experience: (open-ended)

12. **What do you think are the main risks associated with open and citizen science?** (Select all that apply)

☐ Misinterpretation of data
☐ Loss of privacy or intellectual property
☐ Ethical concerns
☐ Lack of expertise
☐ Potential misuse of findings
☐ Other (please specify)

13. **Do you think there is a risk of misinformation or miscommunication when using open and citizen science in the creative society?**

☐ Yes
☐ No
☐ Maybe

14. **What measures should be taken to ensure the ethical use of open and citizen science in communication?**

☐ Ensuring proper attribution of data and ideas
☐ Protecting participants' privacy and personal data
☐ Establishing clear guidelines for transparency and accountability
☐ Preventing the misuse or misrepresentation of scientific data
☐ Ensuring the inclusion of diverse voices and equitable participation

- ☐ Maintaining the integrity of scientific research and findings
- ☐ Implementing ethical review processes for citizen-led projects
- ☐ Other (please specify)

15. How do you think open and citizen science could be misused in creative fields?

- ☐ Misrepresentation or distortion of scientific data for artistic or commercial purposes
- ☐ Exploitation of citizen scientists' contributions without proper recognition or compensation
- ☐ Use of scientific findings to support biased or misleading narratives
- ☐ Ethical concerns in data collection, including privacy violations or lack of informed consent
- ☐ Oversimplification of complex scientific concepts for creative storytelling, leading to misinformation
- ☐ Commercial exploitation of community-driven projects without benefiting participants
- ☐ Appropriation of indigenous or local knowledge without respect for cultural contexts
- ☐ Other (please specify)

16. What support or resources would you need to participate in open and citizen science actively? (Select all that apply)

- ☐ Training programs
- ☐ Access to data
- ☐ Mentorship or guidance
- ☐ Online platforms for collaboration
- ☐ Other (please specify)

17. Would you be interested in actively participating in open and citizen science projects if given the opportunity?

- ☐ Yes
- ☐ No
- ☐ Maybe

18. How can educational institutions support students and aspirants in engaging with open and citizen science?

- ☐ Incorporating open and citizen science projects into the curriculum
- ☐ Providing access to relevant training, workshops, or online courses
- ☐ Creating platforms for collaboration between students, scientists, and creative professionals
- ☐ Offering grants, funding, or resources for student-led open science initiatives
- ☐ Facilitating mentorship and networking opportunities with experts in the field
- ☐ Encouraging interdisciplinary collaboration between science, arts, and communication departments
- ☐ Promoting awareness and engagement through extracurricular activities and clubs
- ☐ Providing access to open data and resources for creative projects
- ☐ Other (please specify)

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19. What do you think the future of communication in the creative society looks like with open and citizen science?

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Don't know
Storytelling and media will evolve as greater access to scientific data and public participation increase						
New forms of collaboration between artists, scientists, and the public will emerge						
Open science will change the way creative professionals engage with audiences on social and environmental issues						
Digital platforms and technology will shape the landscape of communication between creative professionals and the public						
Open and citizen science will inspire new artistic movements or communication styles						
Public participation in science will impact the credibility and authenticity of creative works						

20. Do you agree that such potential challenges might arise in balancing creativity and scientific accuracy in future communications?

Statement	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Don't know
The risk of oversimplifying complex scientific concepts for creative storytelling						
The risk of maintaining artistic freedom while ensuring scientific integrity						
The risk of ensuring accuracy without sacrificing the emotional or artistic impact of the message						
The risk of conflicts between creative interpretation and factual data representation						
The risk of navigating the wrong path between entertaining and educating audiences.0						
The risk of sensationalism or exaggeration to attract attention will override the respect for the data.0						
The risk is that creative works can contribute to misinformation or public misunderstanding.0						
The risk of imbalance in public engagement with the need for expert oversight in scientific communication						

21. Do you have any additional thoughts or suggestions regarding the use of open and citizen science in communication within the creative society? (open-ended)

Note: For agreement-based items, the coding was: 5 = strongly agree; 4 = agree; 3 = neither agree nor disagree; 2 = disagree; 1 = strongly disagree; 0 = don't know. For the frequency variable x3, the coding was: 1 = never; 2 = seldom; 3 = sometimes; 4 = often; 5 = very often.