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CHAPTER 2

ASSESSING STAKEHOLDER PERSPECTIVES ON ESSENTIAL SKILLS IN NANOSCIENCE: WHAT MATTERS MOST?

ABSTRACT

This article presents the results of a study analyzing the relative importance of cognitive, practical-operational, and motivational-value skills for professionals in the field of nanoscience. The study identifies the critical skills necessary for success in this interdisciplinary field based on a survey of various stakeholder groups, such as academic researchers, industry professionals, graduate students, policymakers, and ethicists. The findings show that all respondents consider critical thinking and problem-solving essential. Ethical responsibility and awareness of societal impact also play a significant role, especially among policymakers and ethicists. The identified differences in priorities between stakeholder groups highlight the need for improvements in nanoscience education to ensure the development of professionals equipped to address scientific-technical and ethical challenges. The article discusses potential directions for enhancing educational programs and policies.

KEYWORDS

Nanoscience, skills, critical thinking, ethical responsibility, education, professional training, interdisciplinarity.

Nanoscience and nanotechnology have become key fields in modern science, offering transformative potential in numerous sectors, including electronics, energy, healthcare, and environmental sustainability [1–3]. The interdisciplinary nature of nanoscience integrates principles of physics, chemistry, biology, and engineering, making it a rapidly developing field with far-reaching implications [4–6]. As the field continues to grow, so does the demand for professionals equipped with a diverse skill set capable of driving innovation, ensuring ethical practices, and addressing complex global challenges [7, 8].

Despite the growing importance of nanoscience, there remains a need for a deeper understanding of the specific skills required for professionals in the field. As nanotechnologies permeate scientific research and industry, the need for a comprehensive skill set encompassing technical expertise, cognitive abilities, and ethical responsibility becomes increasingly critical [9]. Previous studies have emphasized the technical competencies needed for nanoscience, such as laboratory methods and computational skills [10, 11], but have often overlooked broader cognitive and motivational-value skills essential for success in such a multidisciplinary environment.

This study aims to analyze the relative importance of three fundamental categories of skills in nanoscience: cognitive skills, practical-operational skills, and motivational-value skills. By surveying a diverse group of stakeholders, including academic researchers, industry professionals, graduate students, policymakers, and ethicists, this research aims to understand the competencies most valued in the nanoscience community comprehensively. This analysis will help identify gaps in current educational and training programs, offer insights into the interdisciplinary demands of the field, and provide recommendations for aligning skill development with the evolving needs of nanoscience.

Understanding the skills needed for professionals in nanoscience is crucial for shaping educational programs and ensuring that future advances in nanotechnology are pursued ethically and responsibly. Thus, this study aims to contribute to both academic and industrial discourse on developing a workforce that is technically proficient, ethically aware, and capable of addressing the complex challenges associated with the rapid advancement of nanotechnologies.

2.1 UKRAINIAN CONTEXT

The ongoing war in Ukraine has revealed two major issues that directly impact the development of nanoscience and the training of specialists in this field. Firstly, the country faces an acute shortage of specialists capable of producing modern nanomaterials for electronic devices, which is critically important for the military-industrial complex [12]. Such materials are needed to make drones, night vision devices, photodetectors, and other components used in air defense systems [13]. This is a vital part of the strategy to ensure national security and strengthen Ukraine's defense capabilities in the face of ongoing threats. The lack of qualified specialists in this field limits the state's ability to meet the technological demands of war and defense effectively.

Secondly, the training of such specialists is also under pressure and requires rethinking in the context of wartime conditions. Specifically, several challenges are complicating this process:

1. Unpopularity of technical specialties among applicants. Due to stereotypes and underestimation of the importance of technical sciences during peacetime, specialties related to nanotechnologies and electronics were not widely popular among young people. The war has demonstrated how critical these skills and knowledge are, but the issue of attracting future students to these fields remains [14].

2. Mismatch between educational programs and labor market needs. Existing academic programs in nanoscience often do not align with the actual demands of the modern labor market, particularly in the context of military and defense technologies. This results in graduates not always possessing the necessary skills and competencies to integrate into the professional sphere, where dual-use technologies are in high demand [15].

3. Difficult conditions for specialist training. Many Ukrainian universities are forced to operate under wartime conditions, often working as "Universities without walls" [16, 17]. Much of the educational process has shifted to an online format, complicating access to laboratory research and experimental training, critically crucial for nanoscience. Additionally, universities are dispersed due to internal and external population migration, with many faculty members and students forced to work or study in other cities or countries [18]. The destruction, damage, or relocation of scientific and educational institutions has significantly reduced the potential for research development [19, 20]. The loss of intellectual capital due to emigration or the inability to work in wartime conditions is also a significant issue for the academic and scientific community [21, 22].

Considering these factors is crucial when planning the development of nanotechnologies in Ukraine. It is necessary to harmonize educational programs with labor market needs, support infrastructure for research and innovation, and create conditions to enhance the appeal of technical specialties among applicants. Successfully addressing these challenges will help Ukraine not only develop high-tech industries but also ensure the stable production of advanced nanomaterials for the defense sector.

For this development to be effective, it is essential to gain a deeper understanding of which skills stakeholders identify as critically important. This will allow for better alignment of educational programs with labor market needs, ensuring that future specialists not only possess technical knowledge but are also capable of responding to the challenges of interdisciplinary research, ethical responsibility, and innovative approaches. Moreover, taking into account the views of various stakeholders (academics, professionals, ethicists, policymakers) will help identify potential gaps in existing training programs and develop strategies to address them, thus contributing to the formation of a highly educated, adaptable, and responsible workforce capable of effectively operating in the face of modern global challenges.

2.2 LITERATURE REVIEW AND RESEARCH QUESTIONS

Developing a competent and adaptive workforce is a crucial condition for success in any industry. To achieve this, it is necessary to equip future professionals with a broad range of skills that will enable them to perform their professional duties effectively, adapt to new conditions, solve problems, and make informed decisions. In general, professional skills are divided into two main categories: "soft skills" and "hard skills" [23].

Soft skills encompass various interpersonal and communication abilities, such as emotional intelligence, teamwork, leadership, time management, critical thinking, and creativity. These skills are essential for successful interaction in both professional and personal relationships, ensuring effective communication and collaboration within teams [24]. The importance of soft skills lies in their universal nature, allowing professionals to adapt to changes, manage conflicts, and make informed decisions in complex situations. For instance, critical thinking is a fundamental tool for analyzing data and finding new approaches to problem-solving, which is particularly important in scientific and engineering activities [25].

Hard skills, in turn, include specialized knowledge and technical abilities directly related to a specific professional activity. These may include skills in working with equipment, software, research methodologies, and understanding of standards and regulations in particular fields [26]. Hard skills can often be measured or certified, making them an explicit criterion for assessing a specialist's competence [27]. In nanoscience, for example, hard skills include expertise in laboratory methods, computational technologies, and modeling skills, which form the basis for conducting precise scientific experiments.

Recently, researchers have increasingly focused on another critical class of skills: transversal or transferable skills [28]. These skills cover relevant competencies across multiple professional fields and can be transferred from one area to another, regardless of task or context specifics. Transversal skills include adaptability, creativity, critical thinking, communication abilities, teamwork, ethical responsibility, and digital literacy [29]. Their universality enables professionals to remain effective and productive amid rapid changes, which is especially important in today's world, where technology and market demands constantly evolve.

Creativity and innovation are becoming increasingly important in modern scientific and technological environments [30]. They allow for the discovery of unconventional solutions and the generation of new approaches to problem-solving, which is often crucial in research areas like nanoscience. Critical thinking enables the analysis and evaluation of information, making fact-based conclusions, and finding new opportunities for development and improvement.

Communication skills, particularly the ability to effectively communicate with colleagues, supervisors, partners, and broader audiences, are crucial for successful professional development [31]. They facilitate the effective exchange of ideas and information, which is necessary for working in interdisciplinary teams, which are common in fields like nanoscience. The ability to work in teams, supporting collective efforts and ensuring coordinated group work, is a vital part of modern scientific and industrial projects, where knowledge and experience from various fields need to be combined.

Adaptability and flexibility are increasingly significant in rapidly changing technologies and market demands [32]. Professionals must quickly adapt to new conditions, master new technologies, and adjust their work approaches. This is particularly important in science, where discoveries and technologies can rapidly change how research is conducted and solve problems.

Digital literacy, which includes proficiency with modern digital tools and technologies, is also integral to transversal skills [33]. With technological advancements and automation, many aspects of scientific and professional tasks require professionals to be proficient with digital data collection, analysis, and presentation tools. This ensures the quick and accurate completion of tasks, enhancing work efficiency.

Ethical awareness and social responsibility are essential in transversal skills [34]. With the rapid development of technologies like nanoscience, it is necessary to consider their impact on society and the environment, ensuring the responsible use of knowledge and achievements. This skill helps professionals make well-informed decisions, evaluating potential risks and long-term consequences of their actions.

Thus, transversal skills provide professionals with technical and interpersonal abilities as well as the capacity to adapt, think critically, and make responsible decisions in the face of rapid changes and complex tasks. Their universality and flexibility make these skills an important component of professional training in any field, including nanoscience, where various disciplines and work methods intersect.

Nevertheless, despite the importance of all skills – soft, complex, and transversal – there is a need to establish professional skills as they define a specialist's qualification and readiness for professional activities. Professional skills, often specific to each industry, are critical for successfully executing tasks as they provide the necessary knowledge and technical proficiency, enabling professionals to operate effectively within their field.

These skills form the foundation of professional competence, a vital indicator of a specialist's readiness to perform specific job functions and meet industry standards. Without appropriate professional skills, which may encompass knowledge of particular methods, equipment, software, or regulations, a professional cannot fully realize their potential and meet the demands of the modern labor market. Professional skills allow the transition from theoretical knowledge to practical application in real-world conditions, ultimately determining career success.

Professional skills can be divided into three main components: practical-operational skills, cognitive skills, and motivational-value skills. These components are essential across various disciplines and emphasize not only the ability to perform specialized tasks but also the broader competencies needed for critical thinking, problem-solving, and ethical decision-making.

Practical-operational skills are typically defined as specific abilities necessary to carry out tasks related to a particular field or profession [35]. These skills often involve hands-on experience with equipment, processes, or methodologies central to a professional's work. In many fields, technical proficiency is considered the foundation of professional activity, as it enables individuals to perform the core functions of their roles.

Cognitive skills, often referred to as "thinking" or "mental" skills, encompass abilities such as critical thinking, analysis, creativity, and the capacity to integrate knowledge from different disciplines [36]. These skills are widely recognized as critically important in professional environments requiring innovation, problem-solving, and adapting to new challenges. Research consistently highlights the importance of cognitive flexibility in navigating complex and dynamic work environments, as professionals must apply their knowledge in new ways.

Motivational-value skills focus on personal qualities, ethical standards, and values that guide a professional's approach to their work [37]. This category includes skills such as moral responsibility, passion for the field, and a commitment to continuous learning. These skills are crucial for fostering a sense of purpose and responsibility, encouraging professionals to strive for excellence and consider the broader societal implications of their work.

In the broader context of professional development, integrating practical-operational, cognitive, and motivational-value skills form a holistic framework that ensures professionals can grow and adapt to changing conditions. Literature from various fields emphasizes that relying solely on technical expertise is insufficient for sustained success [38]. Instead, integrating cognitive skills, such as critical thinking and creativity, allows professionals to navigate complex problems and make informed decisions. Meanwhile, motivational-value skills, such as ethical awareness and passion, ensure their work aligns with personal and societal values.

While many studies have already explored the importance of cognitive, practical-operational, and motivational-value skills across different fields, nanoscience remains relatively under-researched in terms of the specific competencies required for professionals. As an interdisciplinary field, nanoscience integrates elements of physics, chemistry, biology, and engineering, making it more complex and requiring a unique combination of skills not typically demanded by more traditional disciplines.

Nanoscience is a relatively young field, and the precise requirements for professionals are still being formed. The literature primarily focuses on the technical development and application of nanotechnologies [39], often overlooking the human capital needed for their advancement [40]. As a result, there is a gap in understanding not only the technical but also the cognitive and motivational-value skills that professionals need to develop to work effectively in the rapidly progressing nanotechnology field and provide an ethical response to global challenges.

Given nanoscience's interdisciplinary nature and potential impact on society, it is essential to explore the balance between technical skills and broader competencies. Critical thinking, knowledge integration, and ethical responsibility are key elements shaping the future of nanoscience and contributing to its sustainable development.

Considering the gaps in the existing literature regarding the skills required for professionals in nanoscience, this study seeks to answer the following research questions:

1. What is the relative importance of cognitive, practical-operational, and motivational-value skills in nanoscience as perceived by key stakeholders?

2. How do different stakeholder groups, such as academic researchers, industry professionals, graduate students, policymakers, and ethicists, prioritize these skills in nanoscience?

These questions aim to provide a more comprehensive understanding of the skill sets needed for professionals in nanoscience and contribute to the broader discourse on how educational programs and professional development initiatives can be improved to prepare future generations for the field's evolving demands.

2.3 METHODOLOGY

2.3.1 SURVEY DESIGN

2.3.1.1 GENERAL FRAMEWORK OF THE STUDY

The design of our study involved surveying a broad range of stakeholders to validate and further explore the importance of identified skill components for future professionals in the field of nanoscience (**Fig. 2.1**).

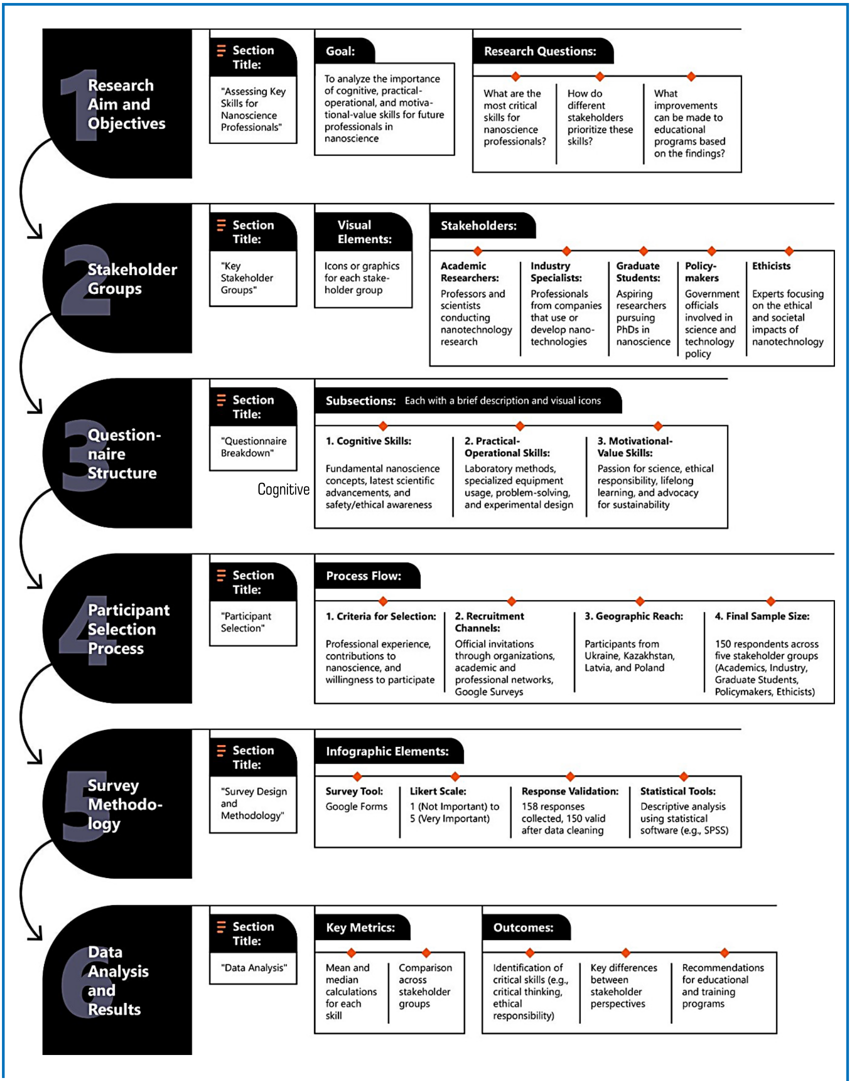

Fig. 2.1 The design of the study

This survey aimed to gather quantitative data on the perceived importance of each skill. A structured questionnaire was developed to assess the relative importance of cognitive, practical-operational, and motivational-value skills among nanoscience professionals. The questionnaire was divided into several sections, each addressing one of the three primary skill types: cognitive, practical-operational, and motivational-value. The participants evaluated the importance of each skill on a Likert scale ranging from 1 to 5, where 1 indicated "not important", and 5 indicated "very important". This allowed us to collect quantitative data on the importance of each skill group among various stakeholders.

2.3.1.2 QUESTIONNAIRE DEVELOPMENT AND VERIFICATION

The questionnaire was developed based on criteria identified as key to studying professional skills in nanoscience. The main criteria for creating the questionnaire included scientific validity, practical relevance, and alignment with the research objectives. Each stage of development was closely linked to the needs of target stakeholder groups and international standards for conducting surveys in scientific research (**Table 2.1**).

Table 2.1 Criteria for questionnaire development

№	Criteria	Description
1	Relevance to research questions	The questionnaire questions were formulated based on the research questions that focused on cognitive, practical-operational, and motivational-value skills in the professional activities of nanoscience specialists. Each question assessed one of the three main types of skills identified in the study. Special attention was paid to ensuring that the questions directly addressed the scientific issues and allowed for a quantitative assessment of the importance of each skill for respondents from various professional spheres
2	Balance and comprehensiveness	During the questionnaire's development, we aimed to create a balanced structure that covered all key aspects of professional skills in nanoscience. We also ensured that all questions addressed different levels of professional development, from graduate students to experienced professionals
3	Simplicity and clarity	One key criterion was ensuring the questions were clear, understandable, and did not mislead the respondents. We avoided complex wording and overly specialized terminology to ensure that different groups of participants correctly understood the questions. Simplicity and clarity were fundamental as the survey covered various professional groups with varying levels of technical expertise

2.3.1.3 PROCESS OF VERIFICATION AND CONSENSUS AMONG AUTHORS

After the questionnaire was developed, each author conducted a thorough analysis and review of the individual questions. Each author reviewed the first version of the questionnaire, evaluating the questions based on criteria such as accuracy of wording, absence of bias, and logical consistency in its structure. All suggested changes or clarifications were carefully examined.

Following these individual reviews, several rounds of discussions were held, during which the authors agreed on the final version of the questionnaire. Each proposed modification's relevance and potential impact on the study results were assessed. In cases where disagreements arose, we referred to scientific sources or consulted external experts for further insights.

Once the critical revisions were agreed upon, the questionnaire was pilot-tested with a small group of respondents from different professional fields. The goal was to assess whether the questions were clear to the respondents, whether there were any difficulties in interpretation, and whether the collected data aligned with our expectations. Minor adjustments were made based on the feedback from this pilot testing.

After the pilot test and final discussions, the authors agreed on the questionnaire's structure and content. The final version was agreed upon, considering all feedback and recommendations, thus creating a tool that fully met the research objectives and adhered to scientific methodology standards.

Therefore, developing and verifying the questionnaire involved several stages of internal review and external testing, ensuring its accuracy, representativeness, and scientific validity.

2.3.2 STRUCTURE OF THE QUESTIONNAIRE

1. **The Introductory Section** of the questionnaire provided general information about the study's purpose and assurances of confidentiality. Participants were informed that their participation was voluntary and that the results would be used exclusively for scientific purposes.

2. **Cognitive Skills Section.** This section included questions aimed at assessing analytical thinking, knowledge of fundamental nanoscience concepts, and the ability to apply the latest advancements in the field. Specifically, participants were asked about:

a) proficiency in fundamental nanoscience concepts;

b) knowledge of the latest scientific achievements in nanoscience;

c) awareness of ethical aspects and safety protocols when working with nanotechnologies.

3. **Practical-Operational Skills Section.** This section evaluated the technical competencies necessary for laboratory and industrial work and the ability to operate specialized equipment. The questions addressed the following aspects:

a) proficiency in laboratory methods specific to nanoscience;

b) skills in operating specialized equipment;

c) ability to plan and conduct scientific experiments;

d) problem-solving abilities and application of critical thinking in research activities.

4. **Motivational-Value Skills Section.** This part of the questionnaire examined the participants' ethical responsibility, values, and motivation for continuous learning. The included questions covered:

a) passion for science and research;

b) commitment to lifelong learning and professional growth;

c) ethical awareness and responsibility in professional activities;
d) advocacy for sustainable practices and awareness of nanoscience's social contribution.

2.3.3 PARTICIPANT SELECTION

Participants were selected from five stakeholder groups representing a broad spectrum of the nanoscience community (**Fig. 2.2**). Efforts were made to ensure a diverse and representative sample, with the largest group consisting of academic researchers due to their direct involvement in nanoscience education and research. The smallest group included ethicists, reflecting the critical role of ethics in nanoscience. Stakeholders were identified and engaged through academic and professional networks, industry partnerships, and connections with educational institutions. The selection criteria included professional experience, contribution to nanoscience, and willingness to participate in the study. Participants were drawn from Ukraine, Republic of Kazakhstan, Republic of Latvia, and Republic of Poland.

The stakeholder groups included **academic researcher** (professors and scientists at universities and research institutions who are actively involved in nanotechnology research); **industry specialists** (specialists from companies that use nanotechnologies, including research and development departments, manufacturing, and application development); **graduate students** (PhD candidates pursuing degrees in nanoscience); **policymakers** (representatives of government and self-governing bodies involved in shaping science and technology policy); **ethicists** (experts specializing in the ethical and social aspects of scientific advances, particularly addressing the ethical implications of nanotechnologies).

We used multiple channels to recruit participants to ensure a wide and representative sample. Official invitations were sent through their organizations to highlight the importance of the study. Additionally, an online Google survey was used to simplify data collection and make it accessible to a broad audience. This multi-channel approach helped to mitigate potential biases and ensure a diverse and comprehensive dataset. It is worth noting that the selection process encountered several challenges, including ensuring balanced representation among stakeholder groups and overcoming potential biases. Furthermore, recruiting ethicists proved challenging due to their relatively minor presence in the nanoscience community, which required targeted outreach to ethics boards and professional organizations specializing in the ethics of science and technology.

At the survey stage, 158 completed questionnaires were initially collected from participants within the defined stakeholder groups. After thorough review and data cleaning, 150 questionnaires were retained for detailed analysis. Specific responses were removed due to issues such as incomplete answers. Additionally, responses containing inconsistencies or contradictions were carefully assessed and excluded to maintain data quality. The distribution of stakeholders who participated in the survey is shown in **Table 2.2**.

Table 2.2 Distribution of respondents by stakeholder categories who participated in the survey

Stakeholders	Number n, (%)
Academic researchers	68 (45.4 %)
Industry specialists	27 (18 %)
Graduate students	29 (19.3 %)
Policymakers	17 (11.3 %)
Ethicists	9 (6 %)

2.3.4 DATA PROCESSING AND ANALYSIS

The collected responses were processed using statistical software to perform descriptive analysis of the mean ratings of the importance of each skill by stakeholder group. Mean and median values for each skill were calculated, providing a comprehensive understanding of how different groups of respondents rate the importance of specific skills in professional activities.

2.4 RESULTS

2.4.1 COGNITIVE SKILLS

The data collected from the surveys were analyzed to determine the importance of skills in the cognitive cluster among various stakeholder groups in the field of nanoscience. **Table 2.3** below presents the average score for each skill on a scale of 1 (not necessary) to 5 (extremely important) for the different stakeholder groups. As shown in **Fig. 2.2**, the comparison of average and median scores for understanding fundamental nanoscience concepts, knowledge of recent advancements, and understanding ethical considerations remains consistently high across different stakeholder groups.

Table 2.3 Importance of cognitive cluster skills as evaluated by various stakeholder groups in the field of nanoscience

Skills	Academic researchers	Industry professionals	Graduate students	Policy-makers	Ethi-cists
Understanding fundamental nanoscience concepts	4.8	4.7	4.6	4.1	4.3
Knowledge of recent advancements and breakthroughs in nanoscience	4.7	4.8	4.5	4.2	4.3
Understanding safety protocols and ethical considerations in nanoscience	4.6	4.6	4.2	4.7	4.8

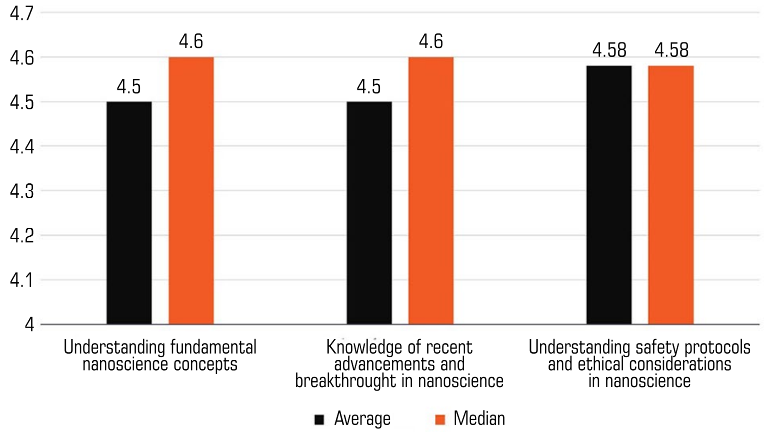

Fig. 2.2 Comparison of average and median importance scores of cognitive skills in the field of nanoscience based on survey results

All stakeholders rated the understanding of fundamental nanoscience concepts highly, with academic researchers giving the highest score (4.8) and policymakers the lowest (4.1). The average score for this skill was 4.5, with a median of 4.6, indicating substantial agreement on the importance of this fundamental skill. Academic researchers, industry professionals, and graduate students showed the highest alignment, with a slight decrease in importance noted by policymakers and ethicists. The observed variation suggests that while practitioners consider it essential, its perceived importance diminishes slightly among those focused on political and ethical aspects of science.

Knowledge of recent advancements and breakthroughs in nanoscience followed a similar pattern: industry professionals rated it the highest (4.8), while policymakers assigned a comparatively lower rating of 4.2. The average score for this skill was also 4.5, with a median of 4.6, demonstrating broad agreement among the groups. Interestingly, industry professionals emphasized staying up-to-date with the latest developments, likely reflecting the need to apply cutting-edge advancements in commercial and research settings. The relatively lower score from policymakers (4.2) may indicate that this group prioritizes broader strategic or regulatory issues over technical advancements.

Understanding safety protocols and ethical considerations in nanoscience showed a somewhat different distribution: ethicists and policymakers rated this skill the highest (4.8 and 4.7, respectively), highlighting the critical importance of this skill in their roles. Graduate students gave the lowest rating (4.2), suggesting a possible gap in emphasis on ethics and safety during early-career training. The average score of 4.58 and a median of 4.6 support the conclusion that this skill is highly valued across all groups but mainly by those responsible for guiding and regulating the ethical and safe use of nanotechnologies. The results indicate a potential for improving education and awareness of ethical considerations and safety for future professionals.

2.4.2 PRACTICAL-OPERATIONAL SKILLS

The assessment of practical-operational skills highlights their importance across all stakeholder groups, though the emphasis varies depending on the participants. The analysis reveals key trends in how different groups perceive the necessity of practical skills for effective work in nanoscience (**Table 2.4**, **Fig. 2.3**).

Table 2.4 Importance of practical-operational skills as evaluated by various stakeholder groups in the field of nanoscience

Skills	**Academic researchers**	**Industry professionals**	**Graduate students**	**Policy-makers**	**Ethi-cists**
Proficiency in laboratory methods specific to nanoscience	4.6	4.4	4.7	3.8	4.3
Competence in computational and analytical methods	4.9	4.6	4.4	4.1	4.0
Ability to plan and conduct scientific experiments	4.8	4.7	4.7	3.9	4.2
Critical thinking and problem solving skills	4.8	4.8	4.8	4.7	4.6

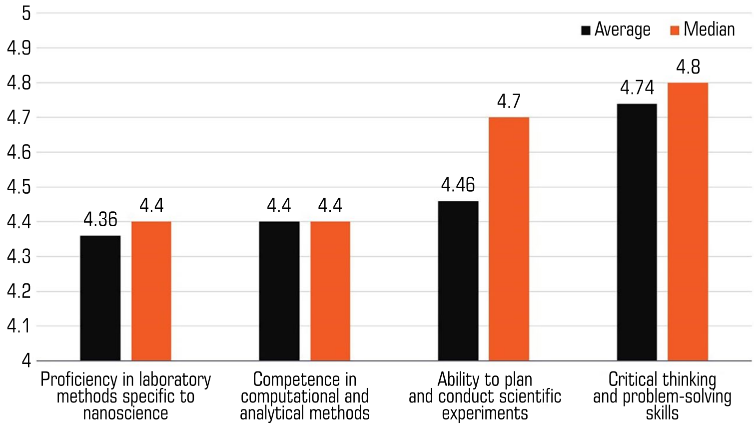

Fig. 2.3 Comparison of average and median importance scores of practical-operational skills in nanoscience based on survey results

Graduate students (4.7) and academic researchers (4.6) rated proficiency in laboratory methods specific to nanoscience highly, while policymakers gave it the lowest score (3.8). The average score was 4.36, with a median of 4.4, indicating an overall positive evaluation of this skill. However, the divergence between academics and policymakers suggests that while practical laboratory competence is critical for researchers and students, it is considered less important in policy-related roles. Ethicists and industry professionals also rated it moderately high (4.3 and 4.4, respectively), underscoring its relevance in both practical and ethical contexts, though to a lesser degree in the political sphere.

Competence in computational and analytical methods received the highest rating from academic researchers (4.9), reflecting the growing importance of data analysis and modeling in nanoscience research. Industry professionals rated this skill slightly lower (4.6), followed by graduate students (4.4), policymakers (4.1), and ethicists (4.0). The average score was 4.4, with a median of 4.4. The lower scores among policymakers and ethicists suggest that computational skills are fundamental for technical roles but are less critical in non-technical functions. The high rating of this skill among academics and industry professionals highlights the need for solid analytical abilities in both research and applied settings.

The ability to plan and conduct scientific experiments was similarly rated by academic researchers, industry professionals, and graduate students (4.8, 4.7, and 4.7, respectively), emphasizing its importance for those actively engaged in scientific research. Policymakers gave it a lower score (3.9), and ethicists rated it moderately (4.2). The average score was 4.46, with a median of 4.7. The ratings reflect that while this skill is vital for research and professional roles, it is perceived as less critical for those in policy or ethics. Nevertheless, the high scores among researchers and students reinforce the central role of planning and executing experiments in advancing nanoscience.

Critical thinking and problem-solving skills received consistently high ratings across all groups, with academic researchers, industry professionals, and graduate students scoring it 4.8. Policymakers and ethicists also rated this skill at 4.7 and 4.6, respectively. The overall average was 4.74, with a median of 4.8, demonstrating that critical thinking and problem-solving are universally valued across all roles in nanoscience. This strong consensus suggests that tackling complex challenges is a crucial competency in research, industry, policy, or ethical contexts.

2.4.3 MOTIVATIONAL AND VALUE-BASED SKILLS

The analysis of motivational and value-based skills among different stakeholder groups highlights how personal commitment, ethical responsibility, and broader societal awareness are perceived in the context of nanoscience. The results lead to the following observations and conclusions (**Table 2.5**, **Fig. 2.4**).

Passion for science received the highest rating from academic researchers (5.0), reflecting deep personal and professional dedication to their field. Graduate students also displayed significant enthusiasm (4.6), while industry specialists rated it slightly lower (4.3). Policymakers (3.9) and ethicists (4.0) rated this skill the lowest, likely reflecting their roles' more strategic and regulatory nature. The overall average score was 4.36, with a median of 4.3. This suggests that while passion for science is fundamental for those directly engaged in research and development, it is perceived as less critical in policy or ethics-related roles, where objective decision-making may take precedence over personal passion.

Table 2.5 Importance of motivational and value-based skills as evaluated by various stakeholder groups in the field of nanoscience

Skills	Academic researchers	Industry professionals	Graduate students	Policy-makers	Ethi-cists
Passion for science	5.0	4.3	4.6	3.9	4.0
Commitment to lifelong learning and professional growth	4.7	4.5	4.3	4.2	4.1
Ethical awareness and responsibility in professional activities	4.5	4.3	4.4	4.7	4.9
Advocacy for sustainable practices in nanoscience	4.1	4.2	4.0	4.8	4.8
Awareness of nanoscience's social contribution	4.2	4.1	4.3	4.9	4.9

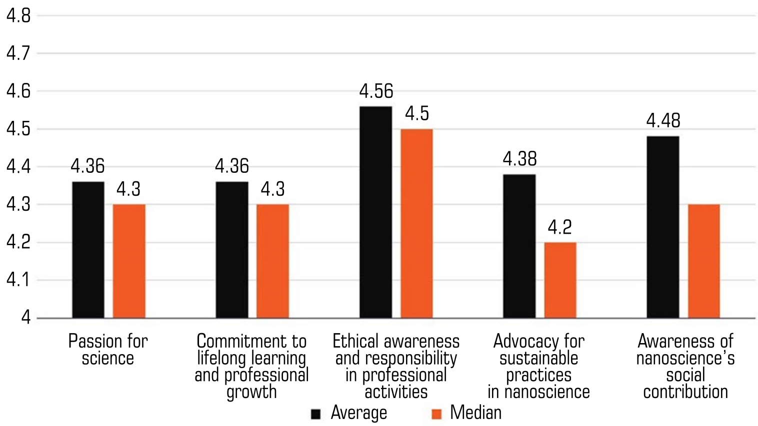

Fig. 2.4 Comparison of average and median importance scores of motivational and value-based skills in nanoscience based on survey results

Commitment to lifelong learning and professional growth was rated highly by academic researchers (4.7) and industry professionals (4.5), emphasizing the importance of continuous development to maintain expertise in nanoscience. Graduate students rated this skill slightly lower (4.3), perhaps because they are focused on completing formal education. Policymakers (4.2) and ethicists (4.1) also recognized the importance of lifelong learning, albeit to a lesser extent. The average score of 4.36 and the median of 4.3 indicate broad recognition of the value of ongoing professional growth across all groups, with researchers and industry professionals prioritizing this aspect.

Ethical awareness and responsibility in professional activities received the highest rating from ethicists (4.9), reflecting their direct involvement in ethical considerations. Policymakers also emphasized this skill (4.7), likely due to their role in ensuring responsible scientific practices. Academic researchers (4.5), industry professionals (4.3), and graduate students (4.4) rated it similarly, with a slightly lower emphasis, possibly because they are more focused on technical expertise. The overall average score of 4.56 and the median of 4.5 reflect the crucial role of ethics across all areas of nanoscience, though mainly for those tasked with regulating and overseeing its use.

Policymakers and ethicists placed the most significant emphasis on advocacy for sustainable practices in nanoscience (4.8 each), reflecting their focus on the long-term consequences and responsible development of technologies. Academic researchers (4.1), industry professionals (4.2), and graduate students (4.0) rated this skill lower, suggesting that sustainability is less of a priority in their daily work compared to broader societal and regulatory concerns. The average score of 4.38 and the median of 4.2 indicate a growing recognition of the need for sustainability, especially among those in leadership and policy roles.

Awareness of nanoscience's social contribution followed a similar pattern: policymakers and ethicists rated it the highest (4.9 each), while researchers, industry professionals, and graduate students rated it slightly lower (4.2, 4.1, and 4.3, respectively). The average score was 4.48, with a median of 4.3, reflecting the importance of understanding nanoscience's contribution to society. This skill is particularly emphasized by those who observe the broader implications of scientific achievements, such as policymakers and ethicists. In contrast, those directly involved in research and development prioritize technical skills over societal awareness.

In summary, all stakeholder groups recognize motivational and value-based skills as necessary, though the level of emphasis varies according to their roles. Passion for science and commitment to lifelong learning are most important for those directly involved in research and industry. At the same time, policymakers and ethicists prioritize ethical responsibility, sustainability, and social awareness. These findings suggest the need for a balanced approach to developing future nanoscience professionals that fosters both technical expertise and a solid commitment to ethical and societal considerations.

2.5 MAIN OBSERVATIONS

2.5.1 COMPARATIVE ANALYSIS

The results of this study provide a comprehensive understanding of the relative importance of cognitive, practical-operational, and motivational-value skills in nanoscience. Among the cognitive skills, understanding safety protocols and ethical considerations received the highest average score (4.58), reflecting growing concerns about safety and moral responsibility in nanotechnologies. Consistently high ratings across stakeholder groups indicate broad agreement on the critical role of these skills in nanoscience, especially among policymakers and ethicists (**Fig. 2.2**). In contrast, knowledge of recent advancements in nanoscience received a slightly lower overall rating (4.5), with policymakers assigning it a lower priority, potentially reflecting their broader focus beyond cutting-edge technological developments.

Regarding practical-operational skills, critical thinking and problem-solving were identified as the most valuable across all groups, with a notably high average score of 4.74 (**Fig. 2.3**). This finding highlights the importance of these skills in tackling complex challenges in nanoscience, transcending technical expertise to include the ability to innovate and solve problems in unpredictable situations. At the same time, proficiency in laboratory methods and competence in computational and analytical methods showed varying importance depending on the stakeholder group. While researchers and industry professionals rated these skills highly, policymakers assigned them lower scores, likely due to their reduced involvement in practical research activities.

In the motivational-value skills category, ethical awareness and responsibility stood out with an average score of 4.56, especially emphasized by ethicists and policymakers (**Fig. 2.4**). Lower scores from students and industry professionals suggest that ethical considerations may not be as deeply integrated into their everyday work or education. Interestingly, passion for science received the highest score from academic researchers (5.0), highlighting its significance for those at the forefront of innovation in nanoscience. Policymakers, however, rated it lower (3.9), indicating a potential difference in how intrinsic motivation is perceived across different sectors.

These findings underscore the need for a balanced approach to developing future professionals in nanoscience, fostering technical knowledge and a solid commitment to ethical and societal considerations. The variation in skill importance across stakeholder groups reflects the diverse nature of the nanoscience field, suggesting that educational and training programs should be tailored to meet the specific needs of different professional roles.

2.5.2 CATEGORY AVERAGES

Cognitive skills had the highest overall average score (4.53), suggesting that understanding core concepts, ethical considerations, and safety protocols is widely seen as essential across all stakeholder groups.

Practical-operational skills followed closely, with an average score of 4.49, reflecting the importance of hands-on expertise and the ability to execute technical tasks in the lab or industry settings.

Motivational-value skills had the lowest average score (4.43), indicating that while personal dedication and ethical responsibility are valued, they may be secondary to technical knowledge and problem-solving abilities.

2.5.3 STAKEHOLDER GROUP ANALYSIS

Academic researchers rated cognitive skills the highest (4.7), followed by practical-operational skills (4.68) and motivational-value skills (4.5). This trend strongly emphasizes theoretical understanding and technical expertise in research environments.

Industry professionals placed the most significant importance on practical-operational skills (4.6), indicating that real-world technical abilities are crucial for success in industrial applications. Cognitive skills were also highly valued (4.53), while motivational-value skills were rated lower (4.3).

Graduate students showed a similar pattern, with practical-operational skills receiving the highest score (4.53), reflecting their need for hands-on experience as they transition into professional roles. Cognitive skills (4.5) and motivational-value skills (4.33) followed.

Policymakers rated motivational-value skills the highest (4.5), emphasizing the importance of ethical responsibility and societal contributions in their decision-making processes. Cognitive skills (4.3) and practical-operational skills (4.0) were rated lower, likely due to the strategic nature of their work.

Ethicists emphasized motivational-value skills (4.6), particularly ethical awareness, followed by cognitive skills (4.4). Practical-operational skills (4.03) were rated lower, reflecting their focus on societal and ethical implications rather than technical expertise.

2.6 DISCUSSION

The comparison of skill categories reveals several significant trends. First, cognitive skills (**Table 2.3**, **Fig. 2.2**) are regarded as the most critical across most stakeholders, particularly academic researchers and policymakers. This finding underscores the central role of theoretical knowledge, ethical considerations, and an understanding of safety protocols in nanoscience. These skills are fundamental for conducting safe and responsible research and ensuring that nanotechnologies are applied ethically.

In contrast, practical-operational skills were rated highest by industry professionals and graduate students who are directly involved in applying nanoscience in real-world settings (**Table 2.4**, **Fig. 2.3**). This highlights the importance of hands-on technical abilities in professional and industrial contexts, where the capacity to operate equipment, run experiments, and solve technical problems is essential for success. The lower emphasis on these skills by policymakers and ethicists suggests that their roles focus on broader ethical and regulatory issues rather than technical competencies.

Motivational-value skills (**Table 2.5**, **Fig. 2.4**), such as a passion for science, ethical responsibility, and lifelong learning, were rated highest by policymakers and ethicists, reflecting their focus on nanotechnology's societal and ethical dimensions. Interestingly, these skills were less emphasized by academic researchers and industry professionals, who placed greater importance on cognitive and practical skills. This divergence suggests that different sectors of the nanoscience field prioritize skills based on their specific roles and responsibilities. For example, researchers and industry professionals may prioritize technical expertise, while policymakers and ethicists are more concerned with long-term sustainability and ethical considerations.

Overall, the results suggest that educational and training programs for nanoscience professionals should be balanced. While cognitive and practical skills are critical for scientific and technical success, motivational-value skills such as ethical awareness and societal responsibility should also be integrated into curricula. This is particularly important given the growing ethical challenges posed by emerging technologies and the need for future professionals to navigate both scientific and societal issues.

In conclusion, this study highlights the varied but interconnected importance of cognitive, practical-operational, and motivational-value skills in nanoscience. The findings suggest that a comprehensive approach to education and professional development is essential for preparing well-rounded nanoscience professionals who are technically proficient, ethically responsible, and socially aware.

2.7 RECOMMENDATIONS

This section presents a set of targeted recommendations to enhance the development of future professionals in nanoscience, focusing on three key levels: educational institutions, industrial and research organizations, and policymakers and ethical bodies. These recommendations address the unique skill requirements identified in the study and provide actionable guidelines to promote a comprehensive approach to professional development in nanoscience. By implementing these recommendations, each stakeholder group can contribute to creating a highly competent workforce, ethically responsible innovation, and sustainable growth in nanotechnology.

2.7.1 RECOMMENDATIONS FOR EDUCATIONAL INSTITUTIONS

Educational institutions should focus on integrating multidisciplinary programs emphasizing cognitive and practical-operational skills (**Table 2.6**). This ensures that students gain a solid theoretical foundation and acquire practical experience necessary for their future work in research and industry settings. Additionally, courses on ethical considerations and social responsibility should be included to enhance motivational-value skills, particularly the awareness of ethics in science and technology. This approach will cultivate responsible professionals capable of making informed decisions. Furthermore, institutions must encourage lifelong learning by offering opportunities for professional growth beyond formal education. This will allow graduates to remain competitive in the rapidly evolving nanotechnology landscape.

Table 2.6 Recommendations for educational institutions

No.	Recommendation	Goal	Purpose
1	Integrate a multidisciplinary curriculum	Develop cognitive and practical-operational skills	Prepare students for research and industry
2	Include ethics and social responsibility modules	Enhance motivational-value skills	Foster responsible attitudes towards ethics
3	Encourage lifelong learning	Promote continuous professional development	Ensure graduates remain competitive

2.7.2 RECOMMENDATIONS FOR INDUSTRY AND RESEARCH ORGANIZATIONS

Industry and research organizations should prioritize hiring candidates with practical, solid skills, ensuring they can handle the technical demands of data processing, experimentation, and equipment operation (**Table 2.7**). A critical aspect is collaboration with educational institutions to offer internships and joint research opportunities, bridging theoretical knowledge with the practical needs of the industry. This collaboration allows students to gain real-world experience, preparing them for immediate employment upon graduation. Moreover, organizations should incorporate ethical responsibility into their innovation processes, ensuring that new technologies are developed considering social and environmental impacts, promoting sustainable development and corporate responsibility.

Table 2.7 Recommendations for industry and research organizations

No.	Recommendation	Goal	Purpose
1	Prioritize practical-operational skills in recruitment	Enhance technical competence	Ensure readiness for technical tasks
2	Collaborate with educational institutions	Foster collaboration for improving professional training	Provide practical experience opportunities for students
3	Incorporate ethical responsibility into innovation	Promote responsible innovation	Support sustainable development and social responsibility

2.7.3 RECOMMENDATIONS FOR POLICYMAKERS AND ETHICAL BODIES

Policymakers and ethical bodies should focus on developing comprehensive regulatory frameworks that govern the safe and responsible use of nanotechnologies (**Table 2.8**). This will establish clear standards that build public trust and support sustainable growth in the sector. Additionally, promoting ethical training programs for scientists and professionals will increase awareness of ethical standards and responsibility in professional activities, fostering a culture of ethical responsibility across industries. It is also crucial to promote public engagement and raise awareness about nanotechnologies by encouraging dialogue on their societal and environmental impacts. This will ensure transparency in decision-making and consider public needs and concerns when implementing new technologies.

Table 2.8 Recommendations for policymakers and ethical bodies

No.	Recommendation	Goal	Purpose
1	Develop comprehensive regulatory frameworks	Ensure safety and responsibility in the use of nanotechnologies	Create clear regulatory standards
2	Support ethical training programs	Increase ethical awareness and responsibility in research	Foster a culture of ethical responsibility
3	Promote public engagement and awareness	Engage society in discussions on the impact of nanotechnologies	Ensure transparency and informed decision-making

By addressing these multi-level recommendations, stakeholders across education, industry, and policy can collectively ensure that nanoscience professionals are technically proficient, ethically responsible, and socially aware. These efforts will contribute to nanotechnology's accountable and sustainable growth, ensuring that it meets the scientific community's and society's needs.

2.8 LIMITATIONS AND PROSPECTS FOR FURTHER RESEARCH

This study presents valuable insights into the importance of cognitive, practical-operational, and motivational-value skills among stakeholders in nanoscience. However, several limitations should be acknowledged. First, the survey scope was limited to a specific set of countries (Ukraine, Republic of Kazakhstan, Republic of Latvia, and Republic of Poland), which may not fully capture global variations in the perceptions of nanoscience skills. Expanding the study to include a broader range of countries with diverse technological and educational landscapes would provide a more comprehensive understanding of how these skills are prioritized internationally.

Second, the sample size, though sufficient for preliminary analysis, may not fully represent the breadth of expertise across all stakeholder groups, particularly for smaller groups such as ethicists. Increasing the number of participants, especially in underrepresented categories, would strengthen the reliability of the findings and allow for more nuanced conclusions.

Another limitation lies in the scope of skills assessed. While the study focused on cognitive, practical, and motivational-value skills, other critical areas, such as leadership, interdisciplinary collaboration, and entrepreneurship, were not explored. Future research could expand the framework to include these additional skill sets, which are increasingly relevant in the evolving landscape of nanoscience.

In terms of prospects for further research, it would be beneficial to conduct longitudinal studies to observe how the importance of these skills shifts over time, particularly as the field of nanotechnology advances. Additionally, exploring how these skills are taught and developed in different educational systems could yield valuable insights into best practices for curriculum design. Further research might also investigate the impact of integrating ethics and sustainability into nanoscience education and training on graduates' professional outcomes and societal contributions.

Finally, a deeper exploration of the relationship between skill development and career success in nanoscience could provide practical guidance for educators and employers. This would help align educational programs with the industry's real-world needs and ensure that future professionals are well-prepared for the field's challenges.

CONCLUSIONS

This study provides valuable insights into the relative importance of cognitive, practical-operational, and motivational-value skills in nanoscience based on the perspectives of various stakeholders, including academic researchers, industry professionals, graduate students, policymakers, and ethicists.

The findings indicate that critical thinking and problem-solving skills are universally recognized as the most important competencies, highlighting the need for educational and training programs to prioritize the development of these skills across all sectors. While cognitive and practical skills, such as competence in computational methods and proficiency in laboratory techniques, are highly valued by researchers and industry professionals, the growing importance of ethical awareness and sustainable practices is particularly evident among policymakers and ethicists. These differences underscore the interdisciplinary demands of nanoscience, where a solid ethical foundation and consideration of societal impact must complement technical expertise.

The study also revealed a potential gap in integrating ethical responsibility into training graduate students and early-career professionals. Addressing this gap through deeper incorporation of ethical considerations into nanoscience curricula can help ensure that future professionals are skilled and aware of the broader consequences of their work.

From a policy perspective, the results suggest that decision-makers should focus on fostering innovation and responsibility in nanoscience. The strong emphasis on sustainable development and societal contribution reflects a growing recognition of the need for technological advancements to align with long-term social and environmental goals.

In conclusion, the dynamic nature of nanoscience requires a balanced approach to skill development, combining cognitive, technical, and ethical competencies. As the field continues to evolve, future efforts should focus on creating more holistic educational frameworks and policies that ensure the next generation of nanoscientists is well-equipped to address the complex challenges of the future.

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