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Dual Use Research: Investigation Across Multiple Science Disciplines

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Abstract Most recent studies of dual use research have focused on the life sciences, although some researchers have suggested that dual use research occurs across many disciplines. This research is an initial investigation into the prevalence of dual use research in other scientific disciplines by surveying senior editors of scientific journals, drawn from Journal Citation Reports. The survey was emailed to 7,500 journal editors with a response rate of 10.1 %. Approximately 4.8 % of life science editors reported they had to consider whether to publish dual use research and 38.9 % said they decided to not publish the research in question. In disciplines other than the life sciences, 7.2 % of editors from other science disciplines reported that they had to consider whether to publish dual use research, and 48.4 % declined to publish it. The survey investigated relationships between dual use and the journal's source of funding and place of publication, but no relationships were found. Further research is needed to better understand the occurrence of dual use research in other science disciplines.

Keywords Dual use · Survey · Science · Scientific disciplines · Research ethics

Introduction

The phrase "dual use" has a long history; originally used to refer to research with both military and civilian applications, it is now also used to refer to research with benevolent and malevolent applications. In the past 15 years or so, concern about

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dual use research has been focused in the life sciences, but other scientific disciplines are relevant as well.

Historical Context

As noted by several scholars, concerns about dual use research date back to the 1600s, with Sir Francis Bacon noting that the results of some experiments were not published (Harris and Steinbruner 2005; McLeish and Nightingale 2007). Dual use research, understood as research with military and civilian applications, became a significant concern during the Atomic Age. Since the 1950s, the U.S. has utilized classification as the primary means to control scientific research related to "weapons systems or nuclear technologies," (Shea 2006, p. 2). Nuclear energy and atomic weapons research is considered "born classified."

Somewhat similar restraints exist for chemical and biological weapons. McLeish (2006) notes that declassified documents "show that advances made in what have been framed as legitimate purposes, i.e. areas including the life sciences and adjacent disciplines, were also applied to the purpose of biological weapons building" (p. 220). Fears about misuse and propagation of harmful toxins prompted the 1972 Biological and Toxin Weapons Convention (and the subsequent 1993 Chemical Weapons Convention) treaty.

Similarly, concern about genetic research led to the 1975 Asilomar Conference on Recombinant DNA which met to "propose and implement voluntary guidelines to reduce the perceived risks to safety from biotechnology" (Kosal 2010, p. 64; see also Fredrickson 1991; Shea 2006). Also in the 1970s, another form of information control was introduced to restrict "the export of domestically developed, advanced, dual-use technologies and technological information" (Shea 2006, p. 2). These export controls typically limit the dissemination of technology, commercial goods, and technical information to other nations.

Contemporary Context

The past two to three decades have seen an evolution in the meaning of dual use beyond the military-civilian connotation. It is now commonly used to refer to research that holds beneficial and harmful potential, particularly in the life sciences. The U.S. National Science Advisory Board for Biosecurity (NSABB) has defined dual use research as "research yielding new technologies or information with the potential for both benevolent and malevolent applications" (NSABB 2007, p. 2). Some life sciences research, the board contends, is particularly susceptible to malevolent use; this has been labeled *dual use research of concern* and has been defined as "life sciences research that, based on current understanding, can be reasonably anticipated to provide knowledge, products, or technologies that could be directly misapplied by others to pose a threat to public health and safety, agricultural crops and other plants, animals, the environment or material" (NSABB 2007, p. 17). Along these lines, reports from the National Research Council (2004) have delineated particular types of experiments of concern and particular "select agents" which pose the most serious risk (such as the smallpox virus).

Many scholars in life sciences have followed the NSABB's lead, using this definition as the basis of their discussions about dual use research. However, others have suggested or adopted broader definitions, which do or may stretch beyond biosecurity and the life sciences (see Table 1). As shown in Table 1, there are a wide variety of approaches to dual use concern; some definitions nearly mirror NSABB's language, while some take a wide-ranging perspective.

The NSABB's focus on the life sciences seems appropriate because of the board's emphasis on biosecurity, as reflected in its name, its members, and its remit. Most of the dual use research that has gained attention in the national popular press in the past few decades has been conducted in the life sciences (Basler, Reid, Dybing, Janczewski, Fanning, Zheng, et al. 2001; Cello et al. 2009; Herfst et al. 2012; Imai et al. 2012; Jackson et al. 2001; Taubenberger et al. 2005).

Previous research has investigated the occurrence of dual use research in the life sciences by examining how frequently it is published or considered for publication. In 2009, van Aken and Hunger surveyed "major life science journals" that included "publication of original research data on human, animal, or plant microbial pathogens (viruses, bacteria, fungi) and toxins" and that had a high impact factor as indicated in Journal Citation Reports (p. 62). These researchers found that two publishing groups, the American Society for Microbiology (ASM) and the Nature Publishing Group, had formal policies regarding the review of potential dual use research, which were implemented across the journals published by these two publishers; other journals did not have formal dual use or biosecurity policies. Resnik et al. (2011) surveyed life science journals to see which had a dual use policy and which had experienced reviewing dual use research. With a response rate of 39 %, they found that only 7.7 % of journals had a written dual use policy and only 5.8 % said they had experience reviewing dual use research. Patrone et al. (2012) surveyed chief editors of life science journals across multiple countries, focusing on life science and medical journals but excluding "categories in the areas of patient care, surgery, nursing, dentistry, law, ethics, and policy" (p. 293). Their survey asked about "the editors' experiences with and attitudes regarding the review and publication of DURC," using the NSABB's definition of DURC. In their sample, 12.5 % of respondents said they believed their journal had published DURC (and a further 25.8 % said they were unsure).

As evident in the scopes of these studies, they have focused explicitly on a somewhat narrow, specific definition of life science and dual use. However, as the publication of Wein and Liu's (2005) paper shows, dual use research is not limited to the life sciences; their work, published in the *Proceedings of the National Academy of the Sciences*, developed mathematical models for the most efficient distribution of the botulism toxin using the U.S. milk supply. Indeed, several scholars urge us to take a broader view of dual use research, beyond the current focus on the life sciences. There are at least two arguments for this.

First, multiple scientific disciplines are rapidly converging or overlapping. For example, Kosal (2010) notes that nanotechnology "spans the fields of physics, biology, and chemistry, and it blurs boundaries between electrical engineering and biomedical engineering and virtually all the disciplines in between" (pp. 58–59). Many scholars note the convergence of biology and chemistry, and the increasing

Table 1 Definitions of dual use research from the literature

Definition	Author
"There are at least three aspects of the dual-use problem… the ostensibly civilian facilities… the agents and equipment used in research… information and knowledge that is generated and disseminated for scientific advancement that might be misused for biowarfare or bioterrorism"	Atlas and Dando (2006)
"How emerging knowledge and techniques (as opposed to bioagents and lab equipment) might figure in the development of biological weapons"	Bezuidenhout and Rappert (2012)
"Research that is beneficial to society that could also pose risks to health or security if used malevolently"	CDC (2007)
"Legitimate and illicit applications both derive from the same science and technology"	Epstein (2012)
"The research potentially has both positive and negative applications"	Fauci and Collins (2012)
"Products, equipments, [sic] or ideas might be malevolently used against people, animals and plants, against progress, and may cause illness, death, panic or disruption in social life"	Keuleyan (2010)
"A wide range of equipment, technologies, and biological material that could be misused for biological weapons purposes; it may also involve the generation or dissemination of scientific knowledge that could be misapplied for such purposes"	Kuhlau et al. (2011)
"Equipment and biological material that could be misused for biological weapons purposes and the generation or dissemination of scientific knowledge that could be misapplied for such purposes"	Kuhlau et al. (2008)
"The tangible and intangible features of technologies which enable them to be applied to both (illegitimate) hostile and peaceful ends with few or no modifications"	McLeish (2006)
"Applied to tangible and intangible features of a technology that enable it to be applied to both hostile and peaceful ends with no, or only minor, modifications"	McLeish and Nightingale (2005)
"Scientific research [that] has the potential to be used for harm as well as for good"	Miller and Selgelid (2008)
"The possible beneficial or malevolent use of reagents, organisms, technologies, or information"	National Research Council (2010)
"Research and technology with the potential both to yield valuable scientific knowledge and to be used for nefarious purposes with serious consequences for public health or the environment"	Pustovit and Williams (2010)
"The potential for findings and techniques to aid both destructive and non-destructive purposes"	Rappert (2008)
"The potential for biological knowledge and biotechnological techniques to serve both beneficial and hostile purposes"	Rappert (2011)
"The possibility of [scientists'] benign civil work being misused by those with malign intent"	Revill and Dando (2008)
"Discoveries [that] have tremendous beneficial impact on health and agriculture but some have equally potential application for harmful use"	Satyanarayana (2011)
"Legitimate and ethically justifiable research, performed in the public interest, and for the public health, may also be relevant to chemical and biological warfare"	Simon and Hersh (2002)
"All elements of knowledge and all tools have many applications—so multiple uses"	Spier (2010)

Table 1 continued

Definition	Author
"The malign or hostile use of peacefully-developed technology against people, animals, or plant life"	Sture (2010)
"Research that is intended for legitimate, beneficial purposes but also carries a risk of being misused for malicious purposes"	Wolinetz (2012)

Note: Many of these authors reference the NSABB definition of dual use, explicitly or implicitly. Because the NSABB definition has already been given in the text of the paper, it is not repeated here. This table captures the authors' own definitions of dual use

role that information technologies play in all of the sciences (Bowman et al. 2011; McLeish 2006; NRC 2010; Resnik 2010). As this convergence continues, non-life scientists will be collaborating on or leading research projects that could have dual use implications; research at the boundary of engineering and biology, for example, may fall outside a strict NSABB-based definition of dual use, yet still contain potentially harmful information.

Second, aside from areas of convergence, other sciences on their own may have dual use potential. Some authors seem to casually mention, then downplay, this possibility. Selgelid (2007) notes in passing that "the dual-use dilemma is commonplace in science, and this is especially true in the life sciences" (p. 39). Epstein (2012) likewise comments: "although other disciplines face dual-use challenges, this article focuses on the life sciences…" (p. 18). Both of these well-respected ethicists acknowledge the (likely) existence of dual use issues outside of the life sciences (see also Resnik 2010; Satyanarayana 2011). Resnik (2010) suggests other relevant areas might include physics, chemistry, medicine, engineering, computer science, and "even social sciences, such as anthropology and psychology" (p. 4). Thus, various scholars have noted the existence, or the likely existence, of dual use research beyond the life sciences.

However, very little is known about the current occurrence of dual use research in the sciences, broadly defined, because the recent research into the occurrence of dual use research has focused on the life sciences (e.g., Patrone, Resnik and Chin 2012; Resnik et al. 2011; van Aken and Hunger 2009); the research described here is a first attempt to sketch its existence and prevalence. Following Resnik and colleagues, this research surveys journal editors from a broad swathe of scientific disciplines to determine the frequency and outcomes of dual use research, beyond the usual life sciences.

Methods

Identification of journals began with the Journal Citation Reports Science Edition 2012 (JCR) from the Web of Science database. This database is recognized as an authoritative collection of the top academic journals across 176 scientific disciplines (as listed in JCR content area scope notes) and has frequently been used to identify top tier journals (i.e., Resnik et al. 2011; van Aken and Hunger 2009). In 2012, JCR listed 8,336 journals in the Science category. Information about all 8,336 journals was downloaded, including journal name, ISBN, impact factor, country of publication, publisher, and language. Next, contact information (name, institution, and email address) was located for the senior editor or editor-in-chief for each journal. After removing duplicates (i.e., individuals who were editors for more than one journal) and journals for which no editor contact information could be found, 7,500 journals with verifiable editor contact information remained.

Using Qualtrics survey software (http://qualtrics.com/), a recruitment email was sent to all 7,500 journal editors. The editors were told the nature and purpose of the survey and given a hyperlink to the survey. The survey was pre-tested with several current and former journal editors and revised according to their suggestions. At the hyperlink, they were provided with a study information sheet approved by the University of Kentucky Institutional Review Board before beginning the survey. At the end of the survey, respondents were given the opportunity to submit their email address if they were willing to be contacted for a follow-up qualitative interview project (which will be discussed in subsequent publications). Journal editors who did not start the survey were contacted with a follow-up reminder after 1 week. The survey was open from July 19 to August 31, 2013.

Overall, 1,261 people began the survey (16.8 % of total possible respondents) and 758 completed the survey (10.1 % of total possible respondents). This is an acceptable response rate for a survey of this size and international scope. It is likely the response rate was relatively low because the survey was conducted during the summer months. In addition, journal editors who thought the survey topic was not relevant to their journal's scope may have declined to participate or may have dropped out of the survey. The survey data was analyzed with Statistical Package for the Social Sciences (SPSS).

Results

Respondents were asked several background questions pertaining to their roles as senior editors of academic journals. Over a third (34 %) of the respondents had been the senior editor of their journal for nine or more years; nearly half (47 %) were the senior editor for five or fewer years. Most of the journals were published in Europe (51 %) or in the United States (38 %). Most editors said their journal was primarily funded by a commercial publisher (45 %) or an academic society or organization (25 %). Respondents were also asked to select the primary academic field of their journal, based on a list drawn from a recent National Science Foundation categorization of disciplines (NSF 2006; see appendix Table 5–39). The discipline categories of JCR were not used because they were too fine-grained and would not have yielded data amenable to statistical analysis. The fields with the most respondents include biology (18 %), clinical medicine (15 %), engineering and technology (13 %), health sciences (12 %), and biomedical research (11 %). Respondents selected the remaining academic fields <10 % each (see Table 2).

Table 2 Academic fields of respondents

Academic field	Response rate (% in parentheses)
Clinical medicine	158 (15)
Biomedical research	119 (11)
Biology	187 (18)
Chemistry	54 (5)
Physics	35 (3)
Earth and space sciences	90 (9)
Engineering and technology	138 (13)
Mathematics	72 (7)
Psychology	18 (2)
Social Sciences	36 (3)
Health Sciences	129 (12)
Professional	21 (2)

Table 3 Explanation of dual use research as provided in the survey

"Dual use" research is research that could potentially generate information that could be misused (for example, by terrorists or criminals). It could cause significant harm to public health, national security, the environment, or the economy.
Although some definitions of dual use focus on the life sciences, dual use research can exist in ANY discipline.
Dual use research is different from classified research (that is, research that is formally classified by the federal government). Research does not need to officially designated "dual use" to actually BE dual use research.

After answering these demographic question, but prior to answering questions about dual use research, respondents were provided with a broad explanation of dual use. This definition was deliberately crafted to apply beyond the life sciences, to determine whether other disciplines also experience dual use research (Table 3).

Respondents were then asked, "In your career as a journal editor, have you ever had to consider whether to publish research that is potentially dual use research (that is, research with the potential to be misused by terrorists or criminals)?" Out of 1,051 total respondents, 93.8 % said they had not, while 6.2 % said they had considered dual use research as a senior editor. Subsequent analysis enabled these responses to be broken down by academic field (see Table 4).

In each academic field, the overwhelming majority of respondents indicated that they had not considered whether to publish dual use research. The academic fields with the lowest levels of positive responses include psychology (0 %), clinical medicine (1.9 %), earth and space sciences (3.3 %), and mathematics (2.9 %).

The academic fields in which dual use was most frequently considered include professional (14.3 %), engineering and technology (11.0 %), chemistry (9.4 %), social sciences (9.1 %), and physics (8.6 %). Interestingly, two life sciences fields, biomedical research and biology, fall in the middle of the pack (5.1 and 7.1 %,

Table 4 Responses to question "In your career as a journal editor, have you ever had to consider whether to publish research that is potentially dual use research (that is, research with the potential to be misused by terrorists or criminals)?"

Primary academic field	Yes (%)	No (%)
Clinical medicine	3 (1.9)	152 (98.1)
Biomedical research	6 (5.1)	111 (94.9)
Biology	13 (7.1)	171 (92.9)
Chemistry	5 (9.4)	48 (90.6)
Physics	3 (8.6)	32 (91.4)
Earth and space sciences	3 (3.3)	87 (96.7)
Engineering and technology	15 (11.0)	121 (89.0)
Mathematics	2 (2.9)	67 (97.1)
Psychology	0 (0)	18 (100)
Social sciences	3 (9.1)	30 (90.9)
Health sciences	8 (6.3)	118 (93.7)
Professional	3 (14.3)	18 (85.7)
Total	64 (6.2)	973 (93.8)

respectively). Of those editors who did have to decide whether to publish dual use research, 69 % (n = 45) indicated they had to make multiple decisions about dual use research. Overwhelmingly, 94 % of senior editors indicated they were solely or primarily responsible for decisions about whether to publish dual use research (thus validating the approach of this and similar work, which focuses upon senior editors).

Editors were also asked who had identified the research as dual use and were allowed to indicate multiple answers; the most frequent responses included the respondent, as the senior editor (80 %, n = 44), the editorial board or other editors of the journal (24 %, n = 13), the peer reviewers of the article (22 %, n = 12), and the researchers themselves (9 %, n = 5).

Editors identified multiple reasons for considering research in the dual use category (see Table 5). The most frequent response was "the research could be used to harm people" (45 %, n = 15), followed by "terrorists, criminals, or other people with malicious intent could utilize the research" (29 %, n = 16), "the research could aid terrorists, criminals, or other people with malicious intent" (29 %, n = 16), and "terrorists, criminals, or other people with malicious intent could access the research" (27 %, n = 15). Editors could add a free-form response for "other reason." Their comments included "could be used to harm the environment," "damage communications," "involved restricted agents," and "Iranian R&D scientists, nuclear and other, seem to have identified this journal as high interest."

Because the response rates for individual academic disciplines were low, several fields were aggregated to provide sufficient statistical power. To create a "life sciences" category, the academic fields of clinical medicine, biomedical research, and biology were combined. The remaining fields (chemistry, physics, earth and space sciences, engineering and technology, mathematics, psychology, social sciences, health sciences, and professional) were combined into an "other science"

Table 5 Reasons to consider research dual use, identified by journal editors

Reasons for considering research to be dual use	Number of positive responses (% parentheses)
The research could be used to harm people	25 (45)
Terrorists, criminals, or other people with malicious intent could UTILIZE the research	16 (29)
The research could aid terrorists, criminals, or other people with malicious intent	16 (29)
Terrorists, criminals, or other people with malicious intent could ACCESS the research	15 (27)
Other reason	11 (20)
The research could be used to harm the United States	9 (16)
The research could be used to harm other nations (not the United States)	8 (15)
The research was dangerous to other nations (not the United States)	4 (75)
The research was dangerous to the United States	4 (7)

Table 6 Funding source of journal in relation to dual use

Primary funding source of journal	Editor had experience with dual use research (% parentheses)	Editor did not have experience with dual use research (% parentheses)
Non-profit	17 (4.7)	344 (95.3)
Other	46 (7.2)	633 (93.2)

$x^2(1) = 2.5505$; $p = 0.110$

category. In these new categories, 4.8 % (n = 22) of life science editors and 7.2 % (n = 42) of other science[1] editors indicated considering dual use research.

Other variables investigated include the funding source of the journal and the journal publication location. For funding source, editors were initially asked whether the primary funding source of their journal was an academic society or organization, a university or other institution of higher learning, a professional society, a government agency, a commercial publisher, not sure, or other. Because of the limited number of responses, these categories were aggregated into two groups: non-profit publishers (academic societies, universities, and government agencies) and all others. As Table 6 shows, the primary funding source of the journal was not significantly related to whether the editors had experienced dual use research ($x^2 = 2.5505$, $p = 0.110$).

To examine whether location of publication was related to dual use research, the following categories were analyzed: North and South America; Europe; and Asia, Australia, and Africa.

[1] Although some fields, such as chemistry and health sciences, could be considered life sciences, they do not account for the majority of positive "other science" responses. Out of the 42 positive responses for other science, only 13 are in chemistry and health sciences.

Table 7 Journal location in relation to dual use

Place where journal is published	Editor had experience with dual use research (% parentheses)	Editor did not have experience with dual use research (% parentheses)
North and South America	32 (7.3)	408 (92.7)
Europe	27 (5.1)	499 (94.9)
Asia, Australia, and Africa	5 (6.7)	70 (93.9)

$x^2(2) = 1.9387$; $p = 0.379$

Table 8 Publication of dual use research

Primary classification	Published dual use research with only minor editorial changes (% parentheses)	Did not publish dual use research (% parentheses)
Life science	11 (61.1)	7 (38.9)
Other science	16 (51.6)	15 (48.4)
Total	27 (55.1)	22 (44.9)

$x^2(1) = 0.4153$; $p = 0.519$

The location of publication was not significantly related to whether the editors had experience with dual use research (see Table 7; $x^2 = 1.9387, p = 0.379$). Separating out the U.S. (38 % of respondents) did not result in statistical significance.

Finally, those editors who indicated experience with dual use research were asked whether they decided to publish the research (see Table 8; $x^2 = 0.4153$; $p = 0.519$; Fisher's exact = 0.0565). As Table 8 indicates, the majority of editors decided to not publish dual use research in their journals. More life science editors declined publication than other science. Overall, 83 % indicated satisfaction with their decision about publication (including both those who published the dual use research and those who did not).

Discussion

Some research in the non-life sciences may be covered by already-existing information control processes, such as export rules and the "born classified" approach in nuclear research. However, it is not difficult to imagine many topics of research which do not fall in those categories. Table 9 provides some examples of potential dual use research for each non-life science discipline.

Evidence exists for some of these topics of dual use research. For example, there is extensive research about agro-terrorism (e.g., Cameron and Pate 2001; Cupp et al. 2004; Foxell 2001; Whellis et al. 2002). Researchers note that "the threat of terrorism on the food supply is real… because of the huge economic, health and social welfare costs associated with food contamination" (Turvey et al. 2010, p. 1). While these authors do not use the term "dual use research," it is clear that some of the research conducted in agricultural science, for example, could be misused with potentially disastrous results.

Table 9 Examples of potential dual use research across non-life science fields

Discipline	Examples of potential dual use research
Chemistry	Knowledge about chemical reactions could be used to create explosions, toxic chemicals, or other harmful effects
	Knowledge of how to utilize technology or sophisticated techniques could lead to chemical weapon creation
Physics	Knowledge about nuclear facilities (location, security, etc.) and radiation could lead to sabotage and purposeful radiation poisoning
	Knowledge of sound frequencies, pitch, and volume could facilitate deliberate manipulation to cause pain or physical damage
Earth and space sciences	Knowledge of wind or meteorological patterns could aid in spread of biochemical weapons, radiation from nuclear weapons, or other harmful airborne substances
	Knowledge of water reservoirs could aid in polluting them or causing manmade drought in particular regions
	Knowledge of satellite orbiting could facilitate damaging or destroying satellites (causing disruption of communication, security, and other infrastructures)
Engineering and technology	Knowledge about the strengths and weaknesses of various structures or building materials could facilitate more effective attacks
	Knowledge of nanotechnology could be misused to invade/infect others
Mathematics	Knowledge of models of dispersal could enlarge impact of toxins or biochemical weapons
	Knowledge of certain formulas could be used to calculate various kinds of attacks
Psychology	Knowledge of "psy-ops" could facilitate psychological torture or abuse of detainees or kidnapped persons
	Knowledge of local family/social customs could facilitate infiltration and attacks
Social sciences	Knowledge of livestock farming procedures or agricultural sowing, harvesting, and transportation could lead to agro-terrorism
	Knowledge of customs or language of indigenous peoples may facilitate raising or quelling coups d'etat
	Knowledge of economic models could facilitate attacks using pathogens
Health sciences	Knowledge of how certain diseases are treated could aid in creating more virulent or toxic variations
	Knowledge of anesthetics could facilitate their misuse or intentional overdose
	Knowledge of epidemiology can facilitate causing or exacerbating outbreaks
Professional	Knowledge about the practical impacts of changes in various trades and technologies could be used to create or spread harmful effects
	Knowledge of components and operation of pacemakers could lead to sabotage and assassination
	Knowledge of experimental techniques or technologies could facilitate development of dangerous pathogens
	Knowledge about physical or cyber infrastructure could lead to targeted attacks

Likewise, Price (2012) describes the misuse of anthropological files on diverse cultures, used by military "for infiltrating and controlling local populations with the aim of advancing the interests of the American military" (p. 18). Kosal (2010) explains some of the security threats of advancing nanotechnology and the likelihood of dual use research in this field. The use of psychology for warfare and the occurrence of cyber-war are both well documented in the popular literature. These brief examples illustrate the occurrence of dual use research in fields where it may not be expected to occur.

Nonetheless, perhaps the most unexpected finding is that 7.2 % of non-life science editors reported addressing dual use research. In fact, every academic field except psychology reported some occurrences of dual use research. The current focus on the life sciences can create the impression that dual use research only or primarily occurs in those fields, but as this research demonstrates, that is not an accurate image.

This may indicate a need for a broader or new definition of dual use that explicitly applies to non-life sciences. Currently, the NSABB is the primary federal institution which studies dual use research and it has an explicit orientation toward the life sciences. It is unclear whether the NSABB's focus could be broadened to consider other scientific disciplines; it is also unclear whether this is needed. Those who believe that dual use research merits more attention and analysis may argue for the creation of a separate board which could focus on the non-life sciences.

The numbers for individual academic fields are too small to be statistically significant; for example, with only 53 chemistry journal editors responding, five of whom reported considering dual use research, we cannot draw statistically significant conclusions. Nonetheless, the results are indicative of at least some dual use research occurring across multiple science disciplines, beyond the life sciences. The higher number of positive responses in the engineering and technology field (11 %; $n = 15$) may not be surprising, as this field deals with the cutting edge of inventions and technical advances; it is likely that some of this research is closely related to life sciences, such as bioengineering.

This research is limited by the relatively small number of respondents and the small proportion who indicated they had experience with dual use research, limiting the statistical power of this data. In addition, editors were not asked about the impact factor of their journals, and due to the anonymous nature of the survey, impact factors could not be identified for those who had completed the survey. Thus, this research does not indicate whether journal impact factor may be related to dual use experience.

Future work can address these weaknesses and add to our knowledge of dual use research across diverse scientific disciplines. Additional surveys targeted to disciplines most likely to experience dual use research (the life sciences and, as indicated here, chemistry and engineering and technology) might result in more responses and therefore more details about dual use research in these fields. Potential respondents could be further refined by examining journal titles and/or scope to pinpoint those likely to experience dual use research. However, caution should be used with this approach; as the current research indicates, dual use research can and does occur in unexpected fields. Because of this, subsequent research examining social science disciplines is called for. In addition, qualitative research which more deeply examines journal editors' thoughts and actions about dual use research would add to our current knowledge.

Conclusion

This research examined whether dual use research occurs in fields other than the life sciences by surveying the editors of top academic journals. While 4.8 % of life science editors reported experience with dual use research, 7.2 % of editors from other science disciplines reported experience with dual use research. This finding suggests that dual use research may need to be defined more generally, and education efforts should include scholars, students, and editors from a broad swath of scientific disciplines, not just life science. Future research can address the limitations of this project and further expand our knowledge of dual use research across many scientific fields.

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