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Altering an appreciative system: Lessons from incorporating dual-use concerns into the responsible science education of biotechnologists

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ABSTRACT

The broad and continuing applicability of Geoffrey Vickers' work owes much to his concern with the human condition in changed and changing circumstances. An important instance of this problem is the relationship between the potential of scientific advances which can greatly enhance human well-being but also find application in new or enhanced weapons of mass destruction. Clearly, preventing such weapons from becoming a normal part of conflict during a period of rapid scientific and technological change in the sciences will require an integrated system of laws and regulations implementing the international agreements. Yet it will also require that the scientific community, through their daily practice and norms of professional conduct, support the efforts to maintain and further develop relevant international treaties that seek to limit the spread of and outlaw such weapons. The purpose of this paper therefore is to examine the utility of Vickers' concept of an Appreciative System for developing a systematic theoretical framework for understanding what change mechanism is efficacious in the education of scientists regarding the extent to which new ideas about ethics and professional responsibility can be grasped, acknowledged and applied.

1. Introduction

In the early years of the publication of *Futures* between 1971 and 1979 the extraordinary polymath Sir Geoffrey Vickers made nine contributions to the journal. These contributions reflected the wide range of his concerns about how the human species would cope with the rapidly changing times at the end of the Enlightenment (Table 1).

These concerns were elaborated in more detail in his series of important books such as *Value Systems and Social Processes* (Vickers, 1968), *Freedom in a Rocking Boat: Changing Values in an Unstable Society* (Vickers, 1972) and *Making Institutions Work* (Vickers, 1973a). Vickers' work continues to be celebrated in the annual Sir Geoffrey Vickers Memorial Award of the International Society for Systems Sciences (ISSS, 2018):

> The Sir Geoffrey Vickers Memorial Award commemorates the life and works of Sir Geoffrey Vickers…. The spirit of his lifework is tremendously contemporary, even though he wrote his most significant works in the early second half of the 20th century: society as evolutionarily emergent; participative and interactive communication as a creative agent; humanization as the necessary normative component of socialization – all this part of what he called 'a science of human ecology.'

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Table 1
Vickers' Papers in Futures.

Year of Publication	Essay Title
1971	*Changing Ethics of Distribution*
1972	*Towards a More Stable State*
	The Management of Conflict
1973	*Wither a Mixed Economy?*
1974	*The Uses and Limits of Policy Analysis*
	Population Policy, Its Scope and Limits
1977	*The Weakness of Western Culture*
1979	*Equality of Responsibility. Cultural Conditions for Western Survival*
	The Future of Morality

Table 2
2017 UNESCO Recommendation on Science and Scientific Researchers (UNESCO, 2017).

III. The Initial Education and Training of Scientific Researchers

12. Member States should have regard for the fact that effective scientific research calls for scientific researchers of integrity and intellectual maturity, combining high, intellectual qualities and respect for ethical principles.

13. To assist the emergence of scientific researchers of this high calibre, Member States should take measures to:

(d) encourage the spirit of service both to the advancement of science and to social and ecological responsibilities toward their fellow nationals, humanity in general, future generations, and the earth including all its ecosystems, its sustainable development and its conservation, as an important element in their education and training;

14. So far as is compatible with the necessary and proper independence of educators and educational institutions, Member States should lend their support to all educational initiatives designed to:

(b) incorporate inter-disciplinary and art and design elements in curricula and courses of all sciences as well as skills such as communication, leadership and management;

(c) incorporate or develop in each domain's curricula and courses the ethical dimensions of science and of research;

(d) develop and use educational techniques for awakening and stimulating such personal qualities and habits of mind as:

(i) the scientific method;

(ii) intellectual integrity, sensitivity to conflict of interest, respect for ethical principles pertaining to research;

(iii) the ability to review a problem or situation in perspective and in proportion, with all its human implications;

(iv) skill in isolating the civic and ethical implications, in issues involving the search for new knowledge and which may at first sight seem to be of a technical nature only;

(v) vigilance as to the probable and possible social and ecological consequences of research and development activities;

(vi) willingness to communicate with others not only in scientific and technological circles but also outside those circles, which implies willingness to work in a team and in a multi-occupational context.

IV. Rights and Responsibilities in Research

The Civic and Ethical Aspect of Scientific Research

16. Member States should encourage conditions that can deliver high-quality science in a responsible manner in line with paragraph 4 of this Recommendation. For this purpose, Member States should establish mechanisms and take all appropriate measures aimed to ensure the fullest exercise, respect, protection and promotion of the rights and responsibilities of scientific researchers and others concerned by this Recommendation. For this purpose:

(a) the following are the recommended responsibilities and rights of scientific researchers:

(iii) to express themselves freely and openly on the ethical, human, scientific, social or ecological value of certain projects, and in those instances where the development of science and technology undermine human welfare, dignity and human rights or is "dual use", they have the right to withdraw from those projects if their conscience so dictates and the right and responsibility to express themselves freely on and to report these concerns.

Given the centrality of Vickers' concerns to considerations of our present-day socio-political, economic and environmental predicaments, it is hardly surprising that his ideas remain in use, something demonstrated in the sets of essays based on his work that were published in 1995 (Blunden & Dando, 1995) and 2005 (Special Issue, 2005).

The broad and continuing applicability of Vickers' work owes much to his concern with the human condition in changed and changing circumstances. His interest was less in the particulars of topical issues and more concerned with how human societies and polities can better understand how we apprehend the world we are rapidly changing. And as the numbers of both world-changing dynamics and significant actors multiply, norms become stressed, consensus becomes more difficult to reach and the framing of public policy for globe-spanning conditions often finds us bewildered, unprepared and divided.

Our difficulties extend beyond the scale and complexities of issues such as climate change to include matters which have vast potential for both good and ill but which, in the first instance are within the deliberative compass of individuals and professional communities. This holds for numerous, recent scientific and technological advances, many of them with far-reaching implications again, both beneficial and pernicious.

An important instance of this problem is the relationship between the potential of scientific advances which can greatly enhance human well-being but also find application in new or enhanced weapons of mass destruction. The emphasis here is on preventing the re-emergence of chemical and biological weapons. Clearly, preventing such weapons from becoming a normal part of conflict during a period of rapid scientific and technological change in chemistry and biology will require an integrated system of laws and regulations implementing the international agreements. Yet it will also require that the scientific community, through their daily practice and norms of professional conduct, support the efforts to maintain and further develop the two critical treaties prohibiting chemical and biological weapons: the Chemical Weapons Convention (CWC) and the Biological and Toxin Weapons Convention (BTWC) (Crowley et al., 2018).

Whilst significant progress has been made over the past two decades in refining the existing and devising new national legal frameworks and formal procedures for strengthening the international ban on the hostile misuse of the chemical and biological sciences, the level of awareness of the problem of dual use – the fact that benignly-intended civil research can be misused later by others with hostile intent (IAP, 2016) – among practising scientists around the world remains low (Dando & Rappert, 2005). Indeed, it seems clear from many investigations over the last decade that few biotechnologists even understand that dual-use applications of their work are possible and that they have some responsibility to help prevent the misuse of their work in the development and potential use of new chemical and biological weapons (NAS, 2017). The existing pervasive lack of awareness of dual- and multi-use potential of breakthroughs is problematic, since, as a result, scientists working at the leading edge of biotechnology may find themselves in ethically charged positions and being exposed to difficult deliberations for which their supporting professional and institutional cultures can leave them unsupported. The factors accounting for this tendency require special attention, not least because current understandings of what constitutes responsible conduct of research in the biosciences and chemical sciences do acknowledge the dual-use conundrum and the related responsibilities incumbent upon researchers. Moreover, it has become increasingly evident that simply trying to lecture scientists about this situation is not going to be productive in engaging them with considering what the dual-use problem is and how they might contribute to addressing the problem (Novossiolova, 2016; Whitby et al., 2015).

The purpose of this paper therefore is to examine the utility of Vickers' concept of an Appreciative System for developing a systematic theoretical framework for understanding what change mechanism is efficacious regarding the extent to which new ideas can be grasped, acknowledged and applied. The paper takes a case-study approach by looking into how issues of dual use and responsible conduct of research can be incorporated into the education of scientists in ways that influence practice. Section 2 briefly introduces the concept of an Appreciative System and Section 3 looks into how it relates to the concept of a professional culture. Section 4 focuses on the issue of dual use within the context of the discourse on responsible science. Section 5 examines the value of active learning, teaching and learning methods in facilitating the practical application of theoretical knowledge. Section 6 enquires into the broader applications of the proposed framework outlining key implications for promoting an Appreciative System change.

2. Vickers' concept of an appreciative system

In 2011 the well-known neuroscientist David Eagleman contributed an essay to the annual Edge Foundation's essay competition. The question was "What scientific concept would improve everybody's cognitive toolkit?" Eagleman's answer was Jakob von Uexkull's concept of the umwelt (Eagleman, 2011). He stated that von Uexkull: "…wanted a word to express a simple (but often overlooked) observation: different animals in the same ecosystem pick up different environmental signals…" and noted Uexkull's famous illustration of the blind and deaf tick only concerned with the temperature and odour of butyric acid from a passing target organism. Other example are fish that live in muddy waters and thus rely on electric sense and bats and dolphins that use sonar systems. As Eagleman noted "[T]he interesting part is that each organism presumably assumes its umwelt to be the entire objective reality 'out there.'" The essay concluded with the observation that "….it would be useful if the concept of the umwelt were embedded in the public lexicon. It neatly captures the idea of limited knowledge, of unobtainable information, and of unimagined possibilities."

An immediate response might often be that applies to animals but surely not to human beings, yet that would be to ignore the modern view that the evolution of the human brain and mind was strongly selected for by the need to master social interactions with other human beings (Gamble et al., 2014). Sir Geoffrey Vickers would certainly have held that view. As he put it in *Human Systems are Different* (Vickers, 1983):

> I find it surprising that we have no accepted word to describe the activity of attaching meaning to communication or the code by which we do so, a code which is constantly confirmed, developed or changes by use. I have for many years referred to this mental activity as 'appreciation'; and to the code which it uses as its 'appreciation system'; and to use the state of the code at any time as the 'appreciative setting'.

The concept of the Appreciative System is indeed found from the beginning of Vickers publications and is central to all of his work. As he noted in his 1965 study *The Art of Judgement* (Vickers, 1965), appreciation consists of the judgement of reality and value though time and that:

> These appreciative judgements reflect the view currently held by those who make them of their interests and responsibilities, views largely implicit and unconscious which none the less condition what events and relations they will regard as relevant or possibly relevant to them, and whether they will regard these as welcome or unwelcome, important or unimportant, demanding or not demanding action or concerns by them…

So, our understanding of the social world may not be as limited as that of other animals, but it is limited by the setting of our appreciative system [inner representations], and although that setting can be changed it will not change easily if the same setting is held by most of the rest of the community of relevance to us. As Vickers noted (Vickers, 1983):

> …we seldom need to do more than update existing inner representations, since our concerns, personal, social, and institutional, and their corresponding representations of the situation relevant to each, are usually continuing or frequently recurring and are constantly reinforced…

Vickers' insight finds corroboration from a moral psychology perspective in the work of Philip Zimabrdo, who devoted his career trying to account for why in certain instances, individuals with a history of moral uprightness commit heinous acts. He concluded:

"Most of us have a tendency both to overestimate the importance of dispositional qualities and to underestimate the importance of situational qualities when trying to understand the causes of other people's behaviour. […] Furthermore, [what is required is] a fuller appreciation of the ways in which situational conditions are created and shaped by higher-order factors—*systems* of power. Systems, not just dispositions and situations, must be taken into account in order to understand complex behaviour patterns" (Zimbardo, 2007).

Zimbardo's work on the social and institutional systems that shape individual behaviours parallels that of Vickers, who argued that it is only if the appreciative system classifies a situation as one that should be changed will a problem be seen to exist, and it is only if a problem is seen to exist will a solution be possible.

In short then, Vickers sees these shared appreciations as the basis for the culture of a particular group:

> Every culture includes an appreciative system which must be at least sufficiently shared to guide collective action, to mediate communication, and to give the society which generates it enough self-confidence to survive. And this interpersonal artefact is sustained and changed by transmission through the series of personal appreciative systems it develops and supports in succeeding generations.

The problem in bringing considerations of dual-use into biotechnologists' conception of responsible conduct then is not one of changing individual minds but of shifting a longstanding culture to a new appreciative setting.

3. Professional cultures as appreciative systems

In basic terms, the concept of culture refers to the established and generally accepted values, mores, practices, routines, norms, and modes of behaviour within a given social grouping. Unlike other spheres of activity such as law, medicine, and accountancy, it was not until the mid-nineteenth century that science came to be regarded as a profession. The pinnacle of the transition process, whereby science practice evolved from an amateur into a professional arena explicitly was the establishment of the term 'scientist' as a professional title (Ross, 1962). Originally coined by William Whewell in 1834, the word served to nurture a sense of unity among individuals specialising in different science sub-fields by denoting their shared commitment to the ideals of truth, originality and objectivity (Ross, 1962). The established norms of practice (e.g. peer review, publication, mentorship) common across various scientific disciplines and the shared outlook on the role of science in society further served to create a particular group mentality which inevitably left a distinctive stamp on scientists (MacIver, 1955). Thus, the consolidation of a professional culture featuring specialised language systems, advanced experimental techniques and accepted modes of behaviour, routines, symbols and rituals effectively gave rise to a scientific community with clearly defined frontiers and a relative degree of sovereignty (Anderson, 1991). The degree to which this community was imagined can be regarded as compelling evidence of scientists' own perceptions of the importance of articulating and reinforcing their nascent professional culture.

Professional cultures rest upon the requirement for technical proficiency in a selected area of specialisation and adherence to a set of norms which shape individuals' behaviour toward colleagues and professionals in other fields, as well as the general public (Wilensky, 1964). Norms constitute concrete, specific and tacit standards that signify what a particular group (or profession) considers acceptable and what unacceptable modes of behaviour (Vickers, 1973b). Norms arise from and crystallize in the emergence of gradual consensus as to what the members of the group perceive as 'normal' and are sustained by a shared recognition of their importance (Vickers, 1973b). They carry significant regulatory weight, insofar as they reflect the ethos of the group, that is, the beliefs, values and morals shared by its members, for which instances of non-compliance may have severe consequences. Thus, conformity with established norms both plays a paramount role in maintaining stability across the group and constitutes an indispensable precondition for the functioning of existing formal rules.

Far from being divorced from moral duty, professional practice is bound to be devoted to a service ideal, often enshrined in a formal code of ethics, according to which quality should not be sacrificed, standards should not be compromised and personal or commercial profit should not be advanced at the expense of public interests (Wilensky, 1964). It is the responsibility of any professional to work toward the promotion and preservation of this ideal by exhibiting collegial respect, refraining from abusing their position of knowledge for personal gain, and by exposing instances of incompetence and unscrupulous practice. Responsibility is in itself a cultural concept: it connotes a set of cultural standards governing the ways in which people who share that culture expect themselves and each other to respond to the requirements which stem from this huge web of relations (Vickers, 1980). Fostering dedication to a professional ethos is thus a requisite element of the process of acquiring a professional role.

The professional paradigm usually begins with a selection and passes through several stages including instruction, apprenticeship, sanctioning, certification and sponsorship (Sherlock & Morris, 1967). Advancing from one stage to another, the prospective professional aims to acquire the knowledge, skills and attributes that will eventually both grant them a full membership in the 'quasi-sacred extra-mundane sphere' of professional communities and allow them to excel in their career (Sherlock & Morris, 1967). Yet the process of professional socialisation is never finished until the individuals have entirely immersed themselves in the culture of the respective profession, that is, until they have become familiar with the argot (e.g. jargon, abbreviations, slogans), values (e.g. rationality, impartiality, commitment to objectivity regarding theory and technique), symbols (e.g. dress, emblems, insignias, heritage, folklore, stereotypes, heroes and villains) etiquette (e.g. formal and unspoken rules for being admitted to a profession, making a career, applying for funds, relating to peers, superiors, or subordinates) and marketplace information (e.g. matrix of activities and opportunities salient to practice) (Greenwood, 1957; Sherlock & Morris, 1967). As a result of the acculturation process, whereby the individual internalises the values, norms, and symbols of the occupational group, the acquired professional status becomes the dominant source of the individual's identity with other sources being voluntarily and, sometimes, forcibly subordinated (Greenwood, 1957; Sherlock & Morris, 1967; MacIver, 1955).

Since professions do not exist in a vacuum but are in a constant interaction with other social groups and structures, cultures of work are hardly sheltered from the influences of the dominant culture within which they operate. That is, in their greatest part, professional norms reflect and are conditioned by the historical and cultural contingencies that have influenced broader social development. Almost any aspect of an individual's career path from occupational training through job selection to professional practice and building a reputation is subject to the mores and morals prevalent in a given community. In modern industrialised states the penetrating influence that the dominant social culture exerts on the cultures of work is explicitly manifested in the way the former shapes and governs the latter. Virtually any culture of work is subject to some form of state regulation. Moreover, the type and extent of regulation that a professional culture requires is bound to vary from one occupation to another, as well as from a country to country. For example, Gelfand et al. distinguish between tight and loose norms, arguing that the tightness and looseness of norms is determined by the degree of formal regulation in a given society:

> [T]he higher (or lower) degree of social regulation that exists at the societal level is mirrored in the higher (or lower) amount of self-regulation at the individual level in tight and loose nations, respectively. Such psychological processes simultaneously reflect and support the strength of social norms and tolerance of deviance in the larger cultural context (Gelfand et al., 2011).

Yet compliance with formal rules and regulations is subject to the vitality of the corresponding professional norms, that is, the extent to which the representatives of a given profession have managed to internalise the requirements codified in national and international laws and guidelines and embed them into their everyday practice.

4. Responsible science, dual use, and the problem of intent

The framework of responsible science provides a context for addressing ethical issues related to the life and chemical sciences, including dual-use concerns and risks of potential hostile misuse (Husbands, 2018). As Husbands notes, the responsible science framework "puts the initial emphasis on *responsibilities* rather than legal obligations" and "makes scientists part of the solution, not part of the problem" (Husbands, 2018). For example, the 1989 edition of *On Being a Scientist* states that:

> Scientists conducting basic research also need to be aware that their work ultimately may have a great impact on society. World-changing discoveries can emerge from seemingly arcane areas of science. The construction of the atomic bomb and the development of recombinant DNA, events that grew out of research into the nucleus of the atom and investigations of certain bacterial enzymes, respectively, are two examples. The occurrence and consequences of discoveries in basic research are virtually impossible to foresee. Nevertheless, the scientific community must recognize the potential for such discoveries and be prepared to address the questions that they raise (NAS, 1989).

The document further states that:

> [Scientists] should not disguise the human factors that motivate and sustain research or the value judgments that inevitably influence science. They should explain and defend the scientific worldview, a prospect of great beauty and grandeur that ought to be a part of how people think about themselves and their place in nature. Scientific research is an intensely human endeavour. This humanity must not be lost in the face science presents to the world (NAS, 1989).

The third edition of *On Being Scientist: A Guide to Responsible Conduct in Research* (NAS, 2009) builds upon the understandings outlined in the 1989 edition:

> The standards of science extend beyond responsibilities that are internal to the scientific community. Researchers also have a responsibility to reflect on how their work and the knowledge they are generating might be used in the broader society. […] [R]esearchers also have the right to express their convictions and work for social change, and these activities need not undercut a rigorous commitment to objectivity in research.

In *Doing Global Science: A Guide to Responsible Conduct in the Global Research Enterprise* that the Interacademy Partnership (IAP) published in 2016, the issue of dual use is addressed in a dedicated chapter:

> The difficulty of predicting the future course and applications of research does not absolve researchers of the responsibility for participating in venues to explore these issues. Researchers need to participate in discussions about the possible consequences of their work, including harmful consequences in planning research projects. […] Society funds research with the expectation that new knowledge will deliver benefits to health, the environment, and overall well-being. It expects researchers to do what they can, within their roles as researchers, to see that promise of research realised (IAP, 2016).

But if the professional responsibility of scientists as codified entails awareness of dual-use issues, why is it the case that in practice the awareness of dual-use issues among those engaged in the life and chemical sciences remains low? One possible explanation could be the lack of a normative acceptance of biosecurity as a vital component of the life science professional culture (Novossiolova, 2015).

At the heart of both the Chemical Weapons Convention and the Biological and Toxin Weapons Convention is the General Purpose Criterion – the allowance that chemical and biological agents, including toxins can be legally used as long as they are not "of types and in quantities that have no justification for prophylactic, protective, or other peaceful purposes." The dual use conundrum is problematic, not least because it concerns benignly intended scientific work that could be misapplied for malicious purposes. Such work is not necessarily limited to particular types of experiments or to the use of certain pathogens, toxins, or chemicals; rather, as the US National Science Advisory Board for Biosecurity acknowledged, "this dual use quality is inherent in a significant portion of life sciences research. In fact, it can be argued that virtually all life sciences research has dual use potential" (NASBB, 2007). Adding to the challenge is the underlying, widely-held belief among scientists that science is by definition neutral since it aims at understanding the world (an objective reality) through discoveries and rigorous study and that the life sciences are beneficent, since they aim at the promotion of health, welfare, and *life* in general. Thus, the idea that biotechnologists could *intentionally* facilitate the development of biological and chemical weapons is alien to the majority of those engaged in the life and chemical sciences. This in turn presupposes that the majority of those engaged in the life and chemical sciences would not readily recognise the issue of dual use as a problem that requires attention. In other words, their appreciative systems are not attuned to the extensive, malign potential of their work.

5. From theory to practice: the benefits of active learning

Promoting a normative acceptance of the need for awareness of security and dual-use issues among scientists requires a change in the tuning of their appreciative system, that is, a change in their professional culture. Evers and Changeux argue that:

> Our cultural and social structures – including our normative reasoning – are important products of the neuronal structures of our brains, but these neuronal structures are also important products of our cultures and societies, and their history. Hence the possibility to influence our brains with the use of culture […], in other words: to invent, learn, and transmit new ethical norms, forming some kind of new ethical languages (Evers & Changeux, 2016).

Education, in their view, equals 'epigenetic proaction':

> What distinguishes the epigenetic educational program is mainly that it is explicitly aimed at favouring individuals as well as cross-generational transmission of ethical/social norms on the basis of our knowledge of the brain (Evers & Changeux, 2016).

A recent report by the US National Academy of Sciences points out the benefits of integrated academic curricula, whereby sciences, arts, and humanities are taught in joint courses, thus allowing students to draw links between disparate fields of knowledge:

> An emerging body of evidence suggests that integration of the arts, humanities, and STEMM [science, technology, engineering, maths, and medicine] fields in higher education is associated with positive learning outcomes that may help students enter the workforce, live enriched lives, and become active and informed members of a modern democracy (NAS, 2018).

Among the principal recommendations of the report is that:

> New designs for general education should consider incorporating interdisciplinary, multidisciplinary, and transdisciplinary integration, emphasising applied and engaged learning and connections between general education and specialized learning throughout the undergraduate years and across the arts, humanities, and STEMM disciplines (NAS, 2018).

An effective strategy to encourage engagement among those in the life and chemical sciences with the issues of the safe use in order to empower them to take a pro-active approach in recognising, addressing and reducing the potential security concerns related to their work is to switch from passive to active learning.

A critical component of active learning is that the learner, rather than the instructor, is at the centre and focus of the activities taking place in the classroom. As such, it is a learner-centred mode of instruction that stresses collaboration, enquiry and critical thinking. Active learning helps people take control of their own learning by enhancing people's abilities to recognise when they understand and when they need more information, thus allowing them to predict their performances on various tasks. Teaching practices congruent with active learning engage learners as active participants in their learning by focussing their attention on critical elements, fostering abstraction of common themes or procedures (principles), and evaluating their own progress toward understanding. Sense-making, self-assessment and reflection on what worked and what needs improving are thus crucial elements of active learning approach.

The US National Academy of Sciences' report *How People Learn: Brain, Mind, Experience, and School* which appeared in 2000 provides an extensive overview of the value and practical uses of teaching approaches that encourage active learning (NAS, 2000). The report shows that there is a substantial body of evidence that active learning approaches enhance learning generally, enabling students to transfer and extend what they have learnt in one context to new contexts. In addition, active learning strategies to instruction have been shown to increase the degree to which students will transfer to new situations without the need for explicit prompting. Overall, the report strongly endorsed the benefits of active learning strategies underscoring that the

> Integration of [active learning] instruction with discipline-based learning can enhance student achievement and develop in students the ability to learn independently. It should be consciously incorporated into curricula across disciplines and age levels (NAS, 2000).

This is particularly important, since there is a substantial body of evidence suggesting that "humans are not adept at making connections between disparate fields or types of knowledge, unless they are specifically helped to do through education" (NAS, 2000; Johnson, 2010).

As the Advisory Board on Education and Outreach (ABEO) of the Organisation for the Prohibition of Chemical Weapons, the organisation charged with implementing the Chemical Weapons Convention, noted in a major report that in part reviewed relevant research in early 2018:

> One of the most important implications of this research is that 'active learning' methods, as opposed to traditional, lecture-based instruction in which students are passive recipients, produce better and longer lasting results. The results hold for factual information and for more fundamental concepts. The methods can be applied in many settings, including the classroom, the laboratory, or the field" (ABEO, 2018).

The ABEO therefore suggests that in the Organisation for the Prohibition of Chemical Weapons' (OPCW) outreach and educational activities there should be a concentration on such active learning methodologies. However, they were well aware of the difficulties, for example pointing out that:

> These insights are important for the OPCW because students, and adults in particular, do not arrive to the classroom as empty vessels into which instructors simply pour new knowledge and insights. They come with a range of experiences and cultural frameworks, on which new understandings are to be constructed. Sometimes a student's prior understandings will support further learning. In other instances, he or she may arrive with pre-conceived ideas or misconceptions that inhibit the capacity to absorb additional information or ideas. Addressing and perhaps changing a student's prior understandings require time and explicit engagement from the instructor. (ABEO, 2018).

Examples of developing and implementing educational programmes on dual-use and security issues among scientists exist (Ukraine et al., 2017; Novossiolova et al., 2018; Whitby & Dando, 2019). One cited model of best practice for promoting security education on an international scale is the International Nuclear Security Education Network (INSEN) that was launched in 2010 (IAEA, 2018a). Together with the International Network for Nuclear Security Training and Support Centres (NSSC), INSEN continues to be a key element of the International Atomic Energy Agency (IAEA)'s long-term strategic vision for building sustainable capacity in the field of nuclear security (IAEA, 2017; IAEA, 2018b).

In 2017, the General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) issued a document titled *Recommendation on Science and Scientific Researchers* which supersedes the 1974 *Recommendation on the Status of Scientific Researchers* (UNESCO, 2017). The revised *Recommendation* contains important provisions concerning the initial education and training of scientific researchers, as well as the civic and ethical aspects of scientific research and related responsibilities and rights of scientific researchers (Table 2). It could be argued therefore that the UNESCO *Recommendation* provides a comprehensive and all-inclusive international framework for promoting security and dual-use education for scientists on a global scale.

6. Implications

This paper has demonstrated that:

1) humans' ability to perceive reality and develop an appreciation thereof is both a precondition for and a manifestation of the prevalent culture and value standards within a given group; and
2) that altering a group's appreciative system requires a change in the fundamentals upon which the group's culture and value standards rest.

Appreciation is both and individual and social process which can hardly be divorced from but is destined to be conditioned by the prevalent political, socio-economic, and cultural setting within which humans operate (Novossiolova, 2017; Whitman, 2010, 2013). Vickers would, of course, be well aware of the difficulties of effectively changing an individual's appreciative system, let alone that of a culture, even by using a moderate approach through education and active learning systems. However, despite these difficulties *The Art of Judgement* ends with a chapter stressing the need for Appreciative Systems to evolve to match the rate of change produced in our societies, particularly as advances in our technology have rendered the Human-Ecological System unstable. Indeed, Vickers contended that "[W]e have created an ungovernable world, in which the natural order and a man-made order are blended as never before into a system which can neither be interpreted by natural nor governed by man-made laws" (Vickers, 1970) which is surely one of the meanings of climate change. Human and natural systems are interdependent and their complex interactions generate multifaceted concerns with cumulative effects that are hard to predict, which inevitably impedes humans' capacity for adaptation:

> "Men are adaptable; they can learn to live even in harsh and hostile environments – so long as the environment remains constant enough to give them time to learn. [...] If they form the habit of adapting by constantly changing that to which they are trying to adapt, they build uncertainty into the very structure of their lives. They institutionalise cluelessness" (Vickers, 1983).

Nevertheless, Vickers' faith in the human capacity to truly appreciate the world-in-the making, to avert catastrophe and work toward human betterment remained considerable. The penultimate paragraph of *The Art of Judgement* emphases the importance of learning in this endeavour:

> For if my analysis is remotely right, the future of our society depends on the speed with which it can *learn*; learn not primarily new ways of responding, though these are needed but primarily new ways of appreciating a situation which is new and new through our own making; and thus finding a basis to combine in securing, so far as we still may, what most belongs to our peace (Vickers, 1965). (original emphasis)

Dealing with the security challenges that humanity faces in the twentieth-first century will certainly require just such a learning process.

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