A transdisciplinary approach to education and training in radiological protection and ALARA.

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Abstract

This text aims at developing an argumentation for an approach to education and training in radiological protection (RP) and ALARA practice that is broader than the 'classical' acquiring of factual knowledge related to physics and regulation. As for most other areas where applications of a technology are connected to a certain risk, the complexity of applications of radioactivity and nuclear technology has generally technical as well as social dimensions.

As well the nuclear worker, the medical doctor as the policy maker or any other person working within an application field of ionising radiation could face situations requiring action where, apparently, the available factual knowledge does not lead unambiguously to a way forward that is 'justified enough' in relation to the potential risk. And if the solution *would* be justified for him/her, it could be that others involved have different opinions. Having this in mind, it is clear that education and training in RP - seen as a continuous learning process - should elaborate on as well the socio-technical complexity of 'risk assessment' as on the conditions and methodologies to 'find a way out'.

Rather than dwelling on methodologies for the organisation of this 'broader' education and training, this paper will analyse elements of complex problem solving and make a link to ethical aspects in order to found the argumentation for this broader approach. We will highlight how the key ideas related to complex problem solving have been translated already in specific methodologies in socio-political science and epistemology.

Based on the philosophical reasoning and on the related (existing) methodologies, we will then argue that the theory and practice of RP could and should develop as a systematic and interactive practice of a diversity of disciplines and skills, and that RP, in this sense, has the potential to serve as a key example of a transdisciplinary interaction of science with society.

The paper then looks at the specific issue of justification and optimisation in the field of applications of low level ionising radiation, and sheds the light on a new approach to optimisation and on some challenges within the scientific community and the broader society.

It will conclude with some examples of the application of the outlined transdisciplinary approach as developed by the Belgian Nuclear Research Centre SCK•CEN.

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Content

0. Introduction

Day to day, radiological protection and safety assessment managers and practitioners are confronted with complex challenges, requiring the input of numerous disciplines, value judgements and the interaction with people in various contexts. In this paper, we argue that radiological protection, although basically integrating a hierarchy of system approaches(based on the ALARA principle) that enable to limit exposure and doses, should also rely on a 'philosophy of ethics' that is inspired also by the ALARA precautionary principle but at the same time acknowledges issues of inherent complexity of 'justification' as such.

In any case, in their character of 'complex problem solving by interaction', both disciplines of radiological protection and safety assessment could (and should) be seen as 'real life' examples of a transdisciplinary approach. This implies that RP education and training on the job, next to the 'classical' generally accepted topics in the field of positive sciences and technology, should be opened up for input from ethics, economy, sociology, psychology,… In this sense, education and training in RP and ALARA should be seen more as 'the practice of - and theoretical reflection on - complex problem solving'; a practice and reflection that include the development of a sense for value judgement and for social (communication) processes.

1. Complexity and the ethical sense

1.1. The real world

As for many other occupations, the learning environment for anyone dealing with radiological protection and ALARA practice includes 'the real world'. While theoretical and practical courses lead to 'factual and methodological knowledge' on the one hand and 'practical knowledge' on the other hand, it is clear that this gathering of information is not always sufficient to be able to act 'responsible' in a real (working) environment. Many times, one is faced with complex situations that not only emerge as technical problems and/or scientific uncertainties, but also (and mostly primarily) as a result of social interaction of the involved people who, in addition, may have different perceptions on the character of the problem as such.

Clearly, 'responsible acting', facing the uncertainty and ambiguity of this kind of situations, is acting

- for which there exists no factual logic or procedures 'in the books';
- that you cannot train in the laboratory;
- for which you cannot always rely on similar (comparable) cases from the past.

Therefore, in addition to the ability to acquire and apply scientific or procedural knowledge, practical expertise in radiological protection should be completed with gaining insight in the complexity of the situation as such. This insight will enable the theorist as well as the practitioner to develop a so-called 'ethical sense'.

1.2. Complexity, risk and injustice

In this paper, we would like to take a step back and first try to understand complexity from out of a more theoretical background. A good start may be the realisation that 'justification', as a way of 'responsible acting' and stating that a practice is justified when it results in 'more benefit than harm', may sound good and 'simple' in theory, but that it is not always workable as a guiding principle in practical situations.

Every justification, including the insight in where and how ethical aspects play a role, obviously has to start from a reflection on the *context* of the practice. Contextualisation, in the sense of analysing which aspects one needs to take into account for a justification of a practice, could in this respect either mean a 'broadening' or a 'delimitation' of the context. A technician who has to judge on the justification of a certain operation in the controlled area of a nuclear power plant may, in addition to the technical argumentation, fall back on more 'simple' ethical criteria but obviously doesn't have to argument the justification of nuclear energy production as such. In a context of sustainable societal development on the other hand, the justification of nuclear electricity production as such may be questioned, and ethical aspects will play a more complex role, taking into account risk governance, involvement of stakeholders and transfer of responsibilities towards future generations. While the use of nuclear technology in medical applications is considered to be justified in a 'conceptual' way, judgement on the necessity and characteristics of every specific practice is still needed.

Judging on whether a certain practice generates 'more benefit than harm' becomes complex when we have to deal with 'context shifts': benefit and harm may emerge in different contexts, or harm may manifest in a larger context, or in a smaller one. The existence of toy fire engines equipped with real ^{241}Am smoke detectors is an example of the first case; coal-fired power plants generating CO_2 or nuclear power plants generating radioactive waste are different examples of the second case; the siting of a RW disposal facility is an example of the third case. The following table shows a simple analysis of the different characteristics of complexity with regard to the justification of a practice.

complexity with regard to the justification of a practice (with a risk or potential hazard):	
technical	uncertainty about cause-effect relation
	'unjust' distribution of benefits and burdens (social, in time, spatial)
technical, political	availability of alternatives
psychological, social	perception of risk ('as such' / related to values)
	perception of the 'justice' of the distribution of benefits and burdens

Next to possible context-shifts, the table also reveals another difficulty when it comes to understanding complexity in this context: the necessity to make a distinction between the potential 'risk' that comes with the practice as such on the one hand, and the 'injustice' that can be generated by the consequences (the distribution of benefits and burdens, and eventually in extent the protection of the 'weak or helpless') on the other hand. The effect of low level radiation on a human individual is an example of the first, while a railroad that passes through (or alongside) private property is an example of the second. Climate change is a phenomenon that shows both characteristics.

1.3. When are ethical aspects relevant?

The context of this paper does not allow to dwell in more detail on complexity and the difference and relation between risk and injustice, but the previous rather lengthy reasoning permits us now to draw a simple conclusion on the issue of ethical aspects associated to activities with a potential risk.

Ethical aspects are relevant in any *interaction* between individuals in a practice with an inherent potential risk and in a context of inherent uncertainty. To be even more specific, one can say that ethical aspects are *only* relevant in interaction processes[4]. In addition, interaction should be understood as direct or indirect: a technician performing an operation that only

[4] In contradiction to the assumption that concepts of 'justice' and 'injustice', and in extent 'good' and 'evil', would exist independently from the existence of the human being as such.

involves a personal risk has the right to be informed about the risk. This information process can be seen as 'indirect interaction' and relates to the well known issue of 'informed consent'. In the same sense, interactions can also be characterised as 'past' or 'future'. Thinking in ethical terms for myself is maybe not relevant when I jump from a bridge, but it might be relevant towards my relatives. In the same sense, ethics become relevant for issues such as euthanasia and radiation risk for the foetus, but also with regard to the siting of a waste disposal near a community.

Referring back to the table that describes complexity with regard to the justification of a practice, one can now understand that ethical considerations play on two interaction levels that can be described as a 'level of deliberation' and a 'level of practice' respectively, and these interactions can be identified as:
- interactions that aim to justify a certain practice with a potential risk *as such* and
- interactions within a specific *justified* practice (with a potential risk) that results in a certain distribution of consequential benefits and burdens.

Deliberation is done in face of a potential risk or urge, while 'practice' can be linked with 'justice' (or injustice). The reader may understand that, in real life, people (inter)act on these levels simultaneously, and that there is 'reflective feedback' from the 'level of practice' to the 'level of deliberation'. A conflict on the issue of the distribution of benefits and burdens may result in the questioning of the justification of the practice as such.

In light of the previous reasoning, radiological protection can now be seen as a field of organised interaction where specific people are nominated to have a responsibility to make judgements - in face of complexity - on actions or practices involving a risk. Although these 'experts' take up responsibility and have a specific authority, our statement that ethical aspects are only relevant in interaction processes brings us to the conclusion that, in this context of 'protection', the 'norms and values' of every involved individual should be treated on the same level.

1.4. Developing an 'applied ethical sense'

Basically, norms describe 'what should (not) be', and values express 'aspects of life that are considered to be important'. Gaining insight in complex problems as characterised above is in fact gaining insight in the 'norms and values' involved. As these values 'by definition' also include the values of the other people involved, this 'learning' implies the willingness (and the ability) to 'broaden the perspective' and to put the issues in context, and this in a two-step approach:

inside	(starting with the 'self')
→	awareness of own knowledge
→	recognise incompleteness and relativity of own knowledge
→	recognise own 'sense for justice'
→	awareness of - and insight in - own values
→	value own reputation with regard to 'credibility'
outside	(looking towards the situation, the others / in context / in perspective) (curiosity / 'the beginner's mind')
→	awareness of (other's) knowledge
→	recognise incompleteness and relativity of knowledge as such
→	awareness of - and insight in - values / context / perspective
→	recognise others 'sense for justice'
→	value others reputation with regard to 'credibility'

One could describe this process as 'developing an ethical sense'. Obviously, an ethical sense is merely an individual issue and should as such not be 'shaped' or 'uniformed' from the outside. Neither should it be seen as a 'final and single end state' that can (or cannot) be reached by everybody. It is known that philosophies of ethics, 'free will' and responsibility don't have the ambition to develop general applicable solutions to ethical (complex) problems, but rather aim at investigating 'possible behaviour' that could lead to better mutual understanding (and subsequently to a kind of 'consensus solution' for the problem at stake).
In this respect, an ethical sense can be considered as a *critical sense* (obviously including a self-critical sense). This sense should not be restricted to a critical stance towards 'the observed outside', but should initially be based on the *willingness to question* own knowledge and views and the *willingness to learn* by opening up the mind for the knowledge and views of others. This attitude is of course no guarantee for a final solution that would have the support of all involved people, but it is certainly a primary condition. In extension, one could thus add the *willingness to seek* win-win 'solutions' by joint problem solving (instead of maximisation of own benefit) as a third step.

2. Basic learning and governance concepts related to complexity

The science of complex problem solving facing uncertainty and risk has led to a number of ideas and concepts that cannot be described in detail in the frame of this text. In general, these ideas and concepts have developed in the frame of research that studies the way technology has an impact on our society (and vice versa). The applications of radioactivity and their impact on society is just but one example.

The three aspects of 'willingness' that were previously identified as key aspects of an 'ethical sense' (or critical sense) can also be seen as the core ideas behind three main concepts that became known in socio-political sciences and science philosophy. In addition to a description of 'personal behaviour', these aspects of 'willingness' form also the basis for applications in the research/learning environment and the governance environment:

2.1. Second mode science (willingness to question own knowledge)

In 'second mode science', the monopoly of science on 'truth' is challenged. "Second mode science, precautionary science, post-normal science share the insight that scientific knowledge is, in essence, a social construct, and therefore the attention is directed towards the context(s) of application of scientific knowledge, rather than to its 'truth' in an absolute sense." [Beck (1992), Risk Society]

2.2. Transdisciplinarity (willingness to learn (from others) - and to learn about methods to learn)

Thanks to the recognition of the intrinsic social dimensions of the complexity of 'impacts of technology on society', well-known disciplines such as 'technology assessment' and 'risk assessment' gradually start to move away from a pure 'rationalist' exact sciences - approach to a more 'transdisciplinary approach' by way of including other disciplines such as philosophy and sociology.

In this sense, transdisciplinarity can be seen as an *attitude* in the research/learning environment or in the governance environment: problem solving oriented thinking and acting across disciplines, taking into account that own (disciplinary) knowledge is always relative. In extension, transdisciplinarity also incorporates so-called 'indigenous knowledge' (knowledge brought into the group by 'non experts' or (local) stakeholders).

Through transdisciplinary learning, the involved practitioners or researchers should f.i. become able to

- interpret and learn from historical lessons
- state and accept uncertainties instead of trying to exclude them
- better understand social mechanisms, also in the working environment
- broaden the risk scope to 'multifactorial concerns' in complex (hazardous) situations
- recognise the relativity of expert knowledge (humility)

"*Transdisciplinarity as a new approach to research and problem solving : the core idea is that researchers, practitioners and stakeholders must cooperate in order to address the complete challenges of society.*" [ETHZ Transdisciplinarity conference, 2000]
"[…] *the transdisciplinary attitude, one which implies putting into practice transcultural, transreligious, transpolitical and transnational visions.* […]" [www.unesco.org]

2.3. Participatory Technology Assessment (pTA) (willingness to learn (from others) - and to (proactively) apply methods to learn)

Participatory Technology Assessment can be described as a process aimed at a systematic investigation of the uncertainties surrounding a certain technological development (regarding as well the 'factual' level as the 'value' level), through an inclusion of a broader range of 'stakeholders' in the assessment process (learning/research environment). In most cases, pTA 'exercises' are organised in the frame of a local or national policy. The result of pTA tools such as focus groups, round tables and consensus conferences can eventually be translated into policy measures (governance environment).

3. Radiological protection as a transdisciplinary field

Responsible acting in the frame of radiological protection (RP) requires first of all good basic knowledge and skills related to the relevant fields of physics, chemistry and technology, and an understanding of relevant biological phenomena as well as of the legislation framework. Historically, RP education and training relying on these 'exact' sciences has been well developed and E&T programmes are integrated more and more in a uniform international quality control system. The previous paragraphs learn us that the assessment capacity related to 'real life' practices (and their risks and related problems) in RP requires also another kind of insight, and this *due to* social and human interactions that characterise the practices *as such*.

In this context, the above described 'ethical sense' can be linked to the capacity to implement the triple system of radiological protection: justification, optimisation and limits, taking into account (and balancing) aspects of 'safety culture' such as technical arguments, costs and benefits, regulatory frameworks, values *and* value judgements, communication processes, negotiation capacities and group dynamics. We want to go even further by stating that the success of RP assessment and decision making requires insight in the social construct of science as such, and that this insight should be part of education and training as well.

Obviously, no individual can (and neither has) to be an 'expert' in all of these aspects. This is why the above mentioned 'deliberative level' of interaction should be part of every safety culture. RP should develop as a systematic and interactive practice of a diversity of disciplines and skills, and has, in this sense, the potential to serve as a key example of a transdisciplinary interaction of science with society. Probably the major 'talents' that all actors should have in common are curiosity in combination with humility, and these talents as such serve as the basis for the development of the above described 'applied ethical sense'.

4. ALARA and optimisation as cornerstones of precaution

Readers with theoretical, managerial and/or practical experiences in RP may agree that, in the frame of the daily practice of RP in areas with low level radiation risk, issues of justification in face of complexity, as outlined in the above philosophical reasoning, can be concentrated around the concept of precaution.

In this practical context, it is known that both justification and optimisation in RP are based on the ALARA principle applied to the (mostly) stochastic nature of risk of exposure. In this sense, ALARA can be seen as a kind of precaution principle 'avant la lettre'. The principle considers uncertainties of risk at low doses but integrates precaution in a preventive legal framework. Meanwhile it is introducing flexible opportunities and allows, although working with a carcinogen, to benefit from the various applications of radiation technology.

4.1. Generating confidence in the context of precaution

Referring back to the table listing the characteristics of complexity, we see that the issue of the applications of ionising radiation involves already the first and basic characteristic: the corrected LNT assumption for the relation between cause and (possible) effect. Therefore, in the context of the three pillar approach, RP first of all requires to take up responsibilities for practices with (un)certain risks already from the ‘first step’ of justification. We stated in previous paragraphs that the development of an ‘applied ethical sense’ with each individual, in combination with a transdisciplinary learning and consultation environment, could generate the necessary confidence to find a way out in any practical case.

4.2. Broadening the working field of optimisation

Furthermore, optimisation developments have worked out in different successful attempts, including tools for innovative ‘broader’ risk management. Indeed, radiological protection overlaps with the field of industrial safety and many institutional approaches, including that of the ICRP, recently extended its attention for ALARA to safety culture. This should include individuals’ safety awareness, safety subcultures and (individuals in) group behaviour.

4.3. Broadening the consultation field for optimisation

Another long awaited innovation in risk management, in particular within radioactive waste management, is stakeholder participation. The context of this paper does not allow to go into more detail, but practical cases in several European countries have proven both the necessity and the success of involving local communities in the siting of radioactive waste disposal sites. Moreover, we welcome the fact that this seems to become an new option in risk governance in general at EU level. Previously, in RP, involvement was limited to consultation of workers. It could now offer also an interesting opportunity for RP policies towards the public at large.

4.4. Precaution, and learning from cultural and scientific challenges

In addition to the inherent complexity of the issues at stake, the science and discipline of radiological protection is also confronted with a variety of challenges ‘from outside’. The challenges include responding to criticism of experts who question the justification of the use of nuclear technology, but also criticism on and ‘cultural resistance’ against the RP system and philosophy as such.

Divergent opinions, such as the one of the French Academy of Medicine on epidemiological science, and on the justification/optimisation regarding the development and opportunities of digital medical technology, are at the core of many actual debates. In addition, more and different research (including on cognitive dissonance) is needed to understand why the ALARA philosophy and system, being successfully implemented in the nuclear industrial sector, still seems to have to cope with a certain reluctance in the medical sector. In this respect, particular challenges include the apparently structured polarisation of positions anchored in different world views (radiologist/hospital physicist) or in certain ethical references (utilitarian use of the average against equity considerations for more risk susceptible individuals).

Next to challenges related to cultural-ideological differences of opinion, RP still has to deal with specific 'gaps' in the basic knowledge (ex. depleted uranium, cardiovascular effects, cataract risk, atmospheric effect of RA noble gases,…). Together with the fast development of molecular biology, also new problems emerged. One of the most important is certainly genetic susceptibility of exposed people and the delicate screening opportunities. Problems of this kind need as well a further development of the basic natural sciences as a reflection on the ethical aspects with all involved parties.

In general, we could say that more than ever, RP institutions and offices as well as individual medical and industrial experts with a relevant responsibility need to develop a more 'critical sense'. They should systematically state uncertainties, be open minded towards technical and cultural elements they do not fully understand (yet), pay attention to public concerns, respect non expert views, common sense and perception of others. In some situations, transparency in communication really requires a cultural change, and explicitation of implicit ethical judgement can help to clarify issues.

4.5. Precaution, and learning from history

To conclude this chapter, we would like to stress the importance of two examples of complex RP issues of the real world that have been 'coloured' due to historical evolutions and that could - in the spirit of this paper - be re-tuned through input from from sociology and psychology:

- *Risk perception* (in the sense of 'the impression of reality'), a phenomenon that, especially in and around the nuclear industry, is not so much directed by rational risk information but rather by a historical lack of interaction between a too much self-confident nuclear industry on the one hand, and an uniformed and uninvolved public on the other hand. This lack of interaction and errors of the past have led to the well-known lack of trust.

- *Group dynamics and human error*: concepts that have been neglected in the earlier development of Probabilistic Safety Assessment (PSA) techniques in reactor safety. The fact that human (and management) reliability were not integrated in the early theory and practical tools of risk assessment has led to an underestimation of the core melt probability.

As a combination of the two, crisis and emergency management can be seen as a 'last but not least' area where RP decision making can still be improved by implementing communication, knowledge management and decision making techniques.

5. Examples of transdisciplinary research related to radiological protection - SCK•CEN's PISA and isRP projects

The use of nuclear technological applications in society can be considered as a complex problem, covering a number of issues such as

- risk, risk management and risk perception
- transgenerational issues
- legal aspects and liability
- interpretation frameworks and values
- expert culture vs social culture

Based on this assumption and dedicated to seek deeper insight in the complexity of these applications and their consequences, the Belgian Nuclear Research Centre SCK•CEN developed projects that are guided by the above mentioned concepts of second mode science and transdisciplinarity.

5.1. PISA (Programme of Integration of Social Aspects into nuclear research)

PISA was developed as an answer to a (self formulated) 'in-house' need 'to better understand ourselves'. Over the years, the experiment has demonstrated already how one can gain broader insight in the complex issues at stake, and a proactive approach and the development of a critical (expert) sense can generate credibility and trust, as well among the staff and researchers, as towards politicians and the general public.

The research, involving human science PhD students, is organised into 5 research tracks:

- Sustainability and nuclear development
- Transgenerational ethics and the disposal of radioactive waste
- Legal aspects and liability
- Risk management
- Experts and ethics

In addition, so-called cross-cutting issues are discussed in reflection groups, involving relevant stakeholders and invited scientists:

- Ethical choices in radiological protection
- Role and culture of the nuclear expert
- Involvement
- Justification and optimisation

More information can be found on www.sckcen.be/pisa

5.2. Cross-over projects of the isRP (international school for Radiological Protection)

Next to coordination and organisation of RP E&T programmes and policy support with regard to applied E&T on both national and international level, the isRP is also involved in research projects. This research concentrates on how to integrate this transdisciplinary approach within education and training programmes for professionals as well as students and pupils.

Pupils have a wide attention span and are eager to learn. In our complex society, they should be able to develop an open and critical mind in order to gain more insight in and confidence towards multi-aspect issues, such as the risks and benefits of radioactivity and nuclear technology, and their possible applications in, for instance, the medical and energy sector. In this sense, isRP interacts with teachers of secondary schools in order to discuss how the standard education programme can integrate a pluralistic approach to complex technical issues, such as the applications of radioactivity. The aim is to identify gaps in the existing curriculum and to find out how to establish links between specific courses and how to organise 'cross-over' sessions in practice.

Towards the general public, isRP works together with visitor centres as well as with regional and Belgian state-sponsored communication activities on physics and nuclear science. In cooperation with SCK•CEN-PISA (Program of Integration of Social Aspects into Nuclear Research), isRP has build up experience with the theory and practice of participation and involvement in technology assessment. On various occasions, the two groups organise round tables, workshops and focus groups with schools and local communities, and this on topics such as medical applications of radioactivity, (nuclear) energy policy and radioactive waste management.

More information can be found on www.sckcen.be/isrp

6. Conclusion

Due to the typical characteristics of ionising radiation, the radiological risk is a very specific one. Risk assessment has to take into account as well scientific uncertainties related to biological effects, the distribution of benefits and burdens as well as different perceptions on the risk and on the usefulness of the specific applications of ionising radiation as such. It is not always easy for theorists and practitioners with a certain responsibility to grasp al the facets and nuances of this risk and of the social dynamics in face of it. This text arguments for a transdisciplinary approach to education and training in radiological protection by stating that practitioners should in a way become prepared to face complex situations that not only emerge as technical problems and/or scientific uncertainties, but also (and mostly primarily) as a result of social interaction of the involved people who, in addition, may have different perceptions on the character of the problem as such.

Transdisciplinarity is an attitude based on the ability to develop a 'critical sense', thus based on the willingness to test own knowledge and views to the knowledge and views of others. This attitude of transdisciplinarity can be acquired through research and in learning processes. By fructifying technical knowledge with ideas from philosophy and sociology, the involved practitioners and stakeholders should be able to gain a better understanding of the complex situation.

E&T should continuously stimulate the development of this critical sense. This sense is an essential 'tool' needed to gain more confidence in the own work and credibility towards the outside world.