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Screw Loose Toolbox

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Screw Loose Toolbox:
24 metaphorical tools to foster the transfer of learning and critical analysis in the realm of technology, nature, society and the individual with democracy as the mediating instance.

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ABSTRACT

Blue Engineering is a student-driven course on the environmental and social responsibility of engineers. It has been developed by student initiatives at two German universities since 2010. By 2023, there are more than 15 courses at universities in Germany and in the Netherlands using the open source course design.
In assessing the learning outcomes of the participants, the need to promote the skill of transfer of learning of the students became clear. This practice paper presents the current approach: 24 metaphorical tools have been developed, each of which functions like a special lens, allowing to recognise certain patterns of action, discussion and collective decision-making that can be identified in many fields.
The *tools* are intended to point out shortcomings in our familiar environment and to offer starting points for the search for possible alternative ways of negotiating, with the normative goal of strengthening democratic process to balance interests.
This paper gives an overview of the competences addressed by the course, defines "transfer of learning" for the research, presents the developed tools and describes their current use in teaching and beyond.
Findings show that the Screw Loose Toolbox can succesfully be used to promote student discussion and reflection. As there are no generally agreed methods to measure transfer of learning and no quantitative results have been obtained.

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1 INTRODUCTION

1.1 The Blue Engineering Course

There is a broad consensus that, in addition to mastering engineering methods, addressing the role of engineers in the necessary transformation of human activity towards a just and sustainable form of economy should play an important role in the education of engineering students. In 2009, a student initiative was formed at TU Berlin to promote discussion of the social and environmental responsibilities of engineers in university teaching. Since then, the innovative approach of the Blue Engineering course has been twofold: a content focus on ethics and social and environmental responsibility, and a student-driven, peer-to-peer approach to teaching. The course design is based on *building blocks* – well-defined and described teaching/learning units that can be facilitated by studens– typically in a workshop atmosphere. The modules are not closely linked and do not need to be taught in any particular order. This allows variations in scope and time for different settings: new combinations of a subset of the available building blocks can easily be formed. In the course of a German semester of approximately thirteen weeks, a wide range of topics is covered.

The course, as taught at TU Berlin, follows a three-phase semester structure: in phase I, student tutors facilitate workshops – so-called *building blocks* – for usually around 100 participating students from a wide range of engineering programmes, with the majority from mechanical and industrial engineering programmes. In phase II, participants facilitate existing building blocks for their peers, before developing and testing new building blocks in phase III.

See Table 1 for an exemplary semester schedule of the course. In addition to facilitating an existing *building block* and designing a new one, students are required to keep a learning journal - a diary-style record of their learning journey.

The documentation of the *building blocks* and the entire course concept have been made available online as Open Educational Resources (OER). Today, courses exist at 15 universities in Germany and the Netherlands, and more than 1500 students have participated in a Blue Engineering course[2].

Table 1. Semester Schedule of the Blue Engineering Course at TU Berlin

Week	Phase	Topic / Building Block	Facilitated by
1	I	Introduction	Tutors
2	I	Plastics	Tutors
3	I	Topic & Group Finding	Tutors
4	I	Technology as Problem-Solver!?	Tutors
5	I	Responsibility and Ethical Codes	Tutors
6	I	The Productivist Worldview	Tutors
7	II	Work, Society and Labour Unions	Students
8	II	25 Questions by Max Frisch	Students
9	II	Automation vs. Good Jobs	Students
10	II	Gender, Diversity and Technology	Students
11	III	New Building Blocks	Students
12	III	New Building Blocks	Students
13	III	New Building Blocks	Students

[2] For more information on Blue Engineering and OER, visit http://blue-engineering.org

1.2 Learning objectives for the course

The project received funding from TU Berlin for innovation in higher education, and accompanying educational research was conducted by (Baier, 2018) from 2012 to 2018. As part of the design research, twelve competences were derived from the frameworks for Education for Sustainable Development and de Haans Gestaltungskompetenz, which the course was designed to address. See Table 2 for the competences. (Baier, 2018) verifies a significant increase in all twelve competencies defined for the course using a quantitative pre-post assessment of participants.

Table 2. Competences addressed by the Blue Engineering course design

Number	Learning Outcomes of the UNIVERSITY COURSE on Module Level
T1-BE	Students take perspectives, change points of view and gather diverse forms of knowledge (i.e. scientific, traditional, common sense) from various actors on the spatial and temporal effects of technology on individuals, society and nature.
T2-BE	Students anticipate spatial and temporal effects of technology on individuals, society and nature.
T3-BE	Students gain knowledge of the reciprocal relations between technology, individuals, nature and society through inter- and transdisciplinary approaches.
T4-BE	Students deal with incomplete and overly complex information on the reciprocal relations between technology, individuals, nature and society and the risks, dangers and uncertainties which arise from them.
C1-BE	Students cooperate for a democratic decision-making with regard to process, result and implementation
C2-BE	Students cope with dilemmas of decision-making when values and aims are conflicting.
C3-BE	Students participate in collective decision-making processes.
C4-BE	Students motivate oneself and others to democratise the reciprocal relations between technology, individuals, nature and society.
A1-BE	Students reflect principles which control the reciprocal relations of technology, individuals, nature and society.
A2-BE	Students identify the underlying values which shape the reciprocal relations of technology, nature, individuals and society and to use them to act morally.
A3-BE	Students plan independently and act autonomously according to one's own values.
A4-BE	Students support others who are disadvantaged due to the dominating design of the reciprocal relations between technology, individuals, nature and society.

1.3 Need for innovation

While the course design was successful in increasing students' competences, the tutoring team reported a recurring observation: students remembered facts and specific arguments from the topics covered, but struggled to recognise more abstract patterns present in different *building blocks*.
Many *building blocks* cover a topic by introducing a specific real-world problem. While gaining knowledge in specific areas is a learning objective, there are additional objectives in each unit that require some kind of abstraction.
For example, in the second week of the TU Berlin course, students role-play a television debate on the pros and cons of using bisphenol A (BPA) in the manufacture of plastics. Reflections on this debate in the learning journals often

remained focused on the details of the BPA debate, rather than linking the role-play debate to public debates about thresholds for potentially harmful substances or the role of science in societal decision-making, which had been introduced in the discussion following the role-play.
This observation was the starting point for the innovation process that eventually led to the creation of a set of metaphorical *tools* called the *Screw Loose Toolbox*. The guiding question throughout the process was: How can memories of underlying meanings or patterns be created that facilitate the recognition of these patterns in different settings and thus the transfer of learning?

2 TRANSFER OF LEARNING

A concise and universally accepted definition of transfer of learning could not be found. (Royer et al. 2005) provide an overview of different schools of thought that have contributed more precise, however not generally compatible definitions of the concept from the broad definition of transfer as "a situation where information learned at one point in time influences performance on information encountered at a later point in time".
(Wolfe et al 2005) promote the distinction between verbatim and gist similarity in explaining cognitive processes contributing to the transfer of learning. Their experiments extend the research on analogical reasoning by (Gentner and Holyoak 1997). They describe the process of analogical thinking as follows: a relevant analog is accessed in memory and then mapped to the target analog – the new situation to be assessed. "Systematic correspondences" between the two are identified, allowing "inferences to be made about the target by borrowing from the base." The results presented by (Wolfe et al 2005) suggest that this process of superimposing new impressions on known, more abstract concepts - gist-based similarity - plays a central role in learning processes that focus less on the reproduction of facts, such as the specific study results on the harmfulness of BPA, and more on the ability to recognise patterns and connections in different processes of a complex living world. This ability is referred to as transfer of learning for this paper.

3 SCREW LOOSE TOOLBOX

3.1 Background

The first step in promoting the memorisation of the more abstract concepts and patterns presented in the course was to make these concepts and patterns more visible to the students. The *Blue Thread* was introduced, a short presentation of new and already known concepts that could be found in a *building block*. Over time, the process of presenting the *Blue Thread* became more standardised: the concepts presented are called *tools*. The collection of *tools* is called the *Screw Loose Toolbox*.
One of the educational methods within the course is the *TINS_D constellation*, which can be used to assess human activities: the reciprocal relations between technology (T), individuals (I), nature (N) and society (S) are examined. As a normative setting, democracy (D) is placed at the centre as a mediating instance for negotiation processes between conflicting interrelations.
Engineering students as the target audience for the course bring to the classroom a focus on problem solving, often considering technical solutions first. However, Blue Engineering has its focus on a dialectic analysis of problems and possible solutions. The idea of *TINS_D* is rooted in Critical Theory and introduces additional dimensions to the analysis of problems and possible solutions. The emphasis on democracy

underlines the normative call for a democratisation of negotiation processes in conflict situations.

The concepts and patterns contained in the *tools* relate to such conflicting relationships. Each *tool* works like a lens that sharpens the contrast to make the encompassed concept easily recognisable, while blurring other possible interpretations of the object being assessed.

The *tools* make it possible to find connections between seemingly distant subjects and to uncover hidden patterns. These patterns are not presented as laws of nature or necessary sequences, but as recurring situations of values in tension. The *tools* are intended to point out deficiencies in our familiar environment and to offer starting points for the search for possible alternative ways of negotiating that strengthen democracy as a normative force for balancing interests.

One important property of each *tool* is a symbolic title: often based on real-world objects or figurative names the titles aim to evoke associations and emotions, thus making it easier to memorise and recognise. Additionally illustrations of each *tool* have been designed giving the *Screw Loose Toolbox* a common identity.

In terms of the theory of analogical reasoning presented above, each *tool* can be understood as a "relevant analog" that can be used to make inferences about the object under assessment - the "target analog" - and thus to generate new knowledge or interpretations of it.

3.2 Examples of the Developed Tools

Back to the building block on BPA in the manufacture of plastics: two *tools* are commonly introduced during the discussion following the role play: The *Slime of the Threshold Limit Value* and the *Poltergeist of the Neutrality of Science* (see Fig. 1).

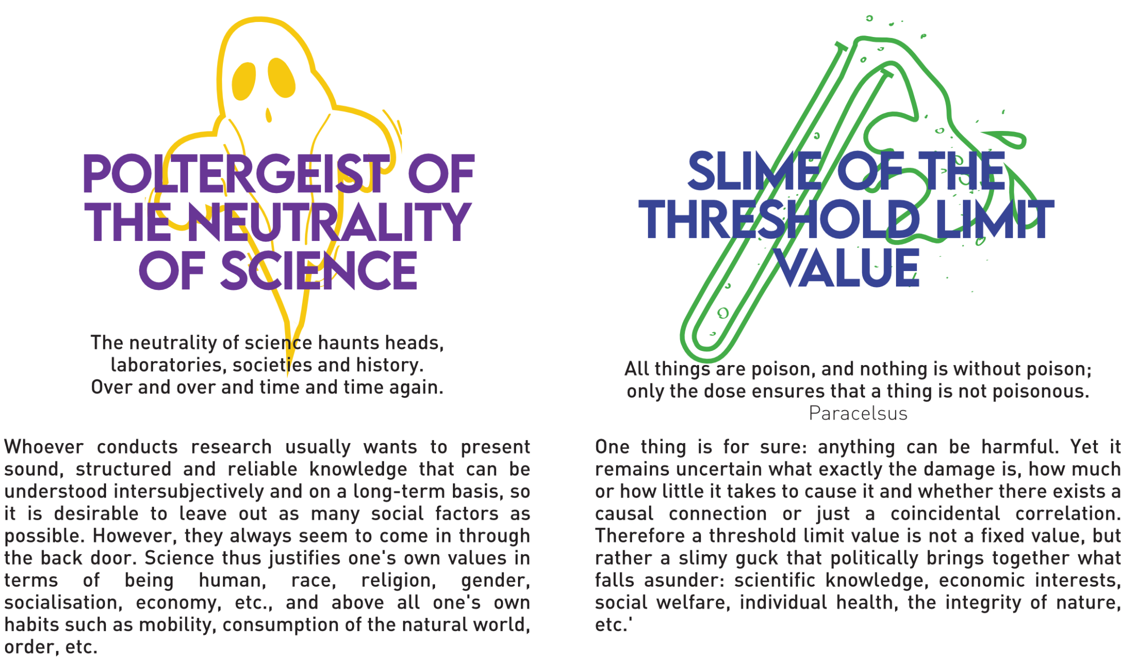

Fig. 1. Poltergeist of the Neutrality of Science and Slime of the Treshold Limit Value

The Slime of the Threshold Limit Value emphasises the double faced nature of limit values: while a limit value seemingly creates a sharp contrast between harmful and non-harmful, legal and illegal, it is always the result of a negotiation process with typically conflicting stakeholders. New scientific insights as well as shifting societal paradigms lead to adjustments of the values, universally correct limit values don't exist. At best, a limit value represents a consensus of a community at a certain place and time. The disputes about the usage of BPA in the manufacture of plastic can be seen as an exemplary case of this relativity of limit values. The limit value for BPA in plastics has been adjusted multiple times over the last decades and the use of the substance has been banned for certain products. However, there is still no unity in the assessments of its harm.

The Poltergeist of the Neutrality of Science focuses on another pattern in the societal subsystem of science: while we as scientists strive for knowledge that is generally accepted and robust to changing contexts we remain highly influenced by our environment: its values, expectations and habitus. If we assess the scientific discourse around BPA in plastics using the lens of the Poltergeist, we recognise that the results of studies vary based on the background of the researchers, the sources of funding and the chosen system boundaries for the research.

3.3 List of all Screw Loose Tools

Beard of the Patriarchy – By the beard of prophets, the patriarchy also has a beard.

Cake for Simultaneously Eating and Keeping – Our dilemma is that we hate change and love it at the same time; what we really want is for things to remain the same but get better. (Sydney J. Harris)

End Credits of the Cat Video – The whole history takes part in the production so that the complete list of contributors is at least as long as the credits of 100 Hollywood movies. (Mathias Greffrath)

Clock that both Measures and Rules – The constraints of the Master become practical constraints and the external constraints turn into self-constraints. Technology not only conceals domination but also establishes and legitimises domination.

Linguistic Habit-Breaker – The language we use develops habits that affect the way we see, hear and think, subsequently shaping ourselves and our society. Once in a while, we have to break these habits to be able to see, hear and think in a new way.

Midas, the Societal King of Destruction – Only when the last tree has died, the last river has been poisoned and the last fish has been caught will we realise we cannot eat money.(Cree Proverb)

Technology's Vicious Cycle – Technology doesn't have to be evil to drive a vicious cycle.

Plastic Dinosaurs of Eternity – Dinosaurs and man, two species separated by 65 million years of evolution, have just been suddenly thrown back into the mix together. How can we possibly have the slightest idea what to expect? (Jurassic Park)

Fire Extinguisher Against the Inferno – It certainly does not hurt to go after a wildfire with one single fire extinguisher, but it won't do much good either.

Fireworks to My Delight and Your Suffering – A little bling-bling to make my own suffering more bearable has always ended up hurting everyone.

Poltergeist of the Neutrality of Science – The neutrality of science haunts heads, laboratories, societies and history. Over and over and time and time again.

Slime of the Threshold Limit Value – All things are poison, and nothing is without poison; only the dose ensures that a thing is not poisonous.   Paracelsus

Mark Twain's Hammer – When your only tool is a hammer, every problem becomes a nail. (Mark Twain)

Happy Meal of the Buy-Yourself-Happy – Buy, buy, buy - for a brief moment you feel alive! Yes, you definitely feel better! Now you are someone! Wait! Not so fast! The next moment you are no one again.
Jam Jar for the Individual – Allein machen sie dich ein. [Alone, they will put you in.] (Ton Steine Scherben)
Ladder of the Higher-Faster-Stronger – With the ladder of the Higher-Faster-Stronger, you can't go to heaven nor anywhere else, because its only goal is to go higher, faster, and further.
Steel Fist of the New Order – If you hit the table with your fist, don't be surprised about a broken table, a broken hand, and broken relationships.
Russian Residual-Risk Roulette – If persons expose themselves to a danger, they assume a risk, meaning that there is a certain probability that they will suffer damage as a result of the danger.
Yardstick of Democracy – The yardstick of democracy measures the capacity of whether all people can participate equally and freely in taking decisions.
Scissors of Inequality – Moreover, inequalities among people as a result of nature are not nearly as great as they become through education. (Johann Gottfried Herder)
Magic Socket of Abracadabra – Like a rabbit from a cylinder, electricity comes from the wall, water from the tap, schnitzel from the supermarket and and and ... with a snap it is gone again and disposed of in the best way.
Straitjacket of Nature – Any attempt to break the compulsion of nature by breaking nature only succumbs more deeply to that compulsion. That has been the trajectory of European civilization. (Adorno/Horkheimer)
TINS_D - Constellation – Technology, individuals, nature, society and democracy (TINS_D) repeatedly form powerful reciprocal relations that create something new and allow old ideals to fade away. These constellations must be both analysed and democratised.
Weight of Requirements – All humans are seen as equal before the law, but their respective needs and requirements carry varying weights in terms of shaping technology and society.

3.4 Use oft the Tools in Teaching

One or two *tools* are usually introduced in every course session and students are encouraged to use the *tools* for the reflection of their learning experience in the learning journal: they map a prescribed base analog to a prescribed target analog. To foster the transfer of learning, students should apply already introduced *tools* to other topics: in the second stage of the semester, small teams of students facilitate existing building blocks for their peers and propose one *tool* that can be used to asses the topic of the *building block*: they select a base analog from a set and map it to a given target analog. In the final part of the course, student teams design new *building blocks* and facilitate them for the other students. By choosing *tools* and topics together, starting points for interpretation can already be considered during the development of the *building blocks*. In this way, students introduce possible mappings between base and target analog and are motivated to introduce points of connection to other topics of the course. This underlines the shift in perspective of the peer-to-peer learning situation, as the students need to consider the stimulation of transfer of learning of their future participants in addition to conveying factual knowledge and problem analyses based on case studies.
In other Blue Engineering courses, further use of the *tools* has been made: students each choose a *tool*, which they then apply to a semester topic such as *nutrition*,

teaching at my university, or *artificial intelligence*. Over the semester, they develop a mapping of the tool to the application field. In a multi-stage review process, short texts (150–400 words each) are developed, refined and supported with sources. At the end of the course, the resulting application texts together with the *tools'* definitions are presented at the university as a small exhibition.

3.5 Exhibition "Rad ab, Schraube locker / Wheel off, short fuse"

Parallel to the use of the *tools* for teaching, the exhibition project "Wheel off, short fuse" was developed. For this purpose, the tools were applied to five subject areas, illustrations of the tools were created and everyday objects were placed in relation to the metaphorical tools as a tangible representation. The exhibition is designed as a touring exhibition and has so far been publicly exhibited at three locations in Germany. An accompanying catalogue with *tool* definitions and application texts has been published; a website presents illustrations and texts in German and English[3].

4 SUMMARY

4.1 Insights

24 *tools* have been defined and form the *Screw Loose Toolbox*. For more than five years these *tools* have been used for teaching at TU Berlin and other Blue Engineering courses. This timespan and the different course settings allow to present the following insights:
1. The *tools* offer various starting points for discussion during the course.
2. The symbolic titles and playful nature of the *tools* make meta-discussions about the reciprocal relations in the tension field of *TINS-D* easier.
3. The *tools* make it possible to see connections between seemingly disparate topics, and introduce a common theme into a course that, due to the peer-to-peer learning approach, covers a wide variety of topics and learning methods presented by constantly changing facilitators.
4. Students adopt the *tools* for the reflection of their learning experience in the learning journals. The share of texts that include parts of transfer of learning has been increased.
5. The use of the *tools* is not limited to the classroom. Exhibitions presenting the metaphorical tools, short texts mapping tools to topics of everyday life and real-world artefacts.

4.2 Limits

The following aspects were identified as being potentially detrimental to students' learning outcomes:
1. interpretations other than those presented by the tools could be suppressed. The presentation of the *Screw Loose Toolbox* and the shared visual identity could suggest a sense of completeness of the set.
2. the stimulus to search for base analogs might be reduced. Studies referred to in (Wolfe et al 2005) show inconsistent results when students are presented with possible base analogues as opposed to being stimulated to produce new analogues. However, doing one does not preclude the other.
The following limitations of the research were identified
1. The design of the *tools* did not follow a formalised process and the tools are not closely linked to the competences defined for the course. Rather, the tools were

[3] See http://screw-loose.org/

designed following a pragmatic approach: with regard to the desired learning outcomes of individual building blocks and possible links between them.
2. A quantitative analysis of the impact of the tools on students' learning outcomes was not carried out. The difficulties of measuring the ability to transfer are described in detail in (Schwartz et al 2005). According to the findings presented there, a robust quantitative assessment would require comparison groups, and even under laboratory conditions the ability to transfer remains difficult to measure.

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