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From Restricting Competencies to Diversifying Competencies: Sustainable Development and its Implications for Competency-Based Approaches to Education

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ABSTRACT

This text proposes a new paradigm for thinking about competency-based education derived from an extended reflection of sustainable development as a wicked problem. It suggests that current approaches to thinking about competences are ill-adapted to dealing with the challenge presented by sustainable development, and based on this conclusion it argues that we need to move from what it calls restricted thinking on competences to diversifying thinking on competences.

1. INTRODUCTION

Sustainable development is one of major challenges confronting the future of humanity. It is also of particular relevance to engineers and other technologists. This is because:

- 1.1 Many of the major environmental issues of today are by-products of the technological transformations that engineering has brought about, and future technological development along the same pathways can and will worsen many current social and environmental issues.
- 1.2 Despite all of the failures and shortcomings of technological progress, there seems to be no alternative to technology but more, better, and different kinds of technological innovations.

In other words, engineers are both actors in creating the current unsustainability of the modern age and key agents towards realizing any future sustainable society.

The particular relevance of sustainable development to engineers means that sustainable development is also a major concern for engineering education. The following pages will take up one aspect of this reframing of engineering education, with a particular focus on the popular educational model of competency-based thinking. The argument presented below has two parts. The first argues that that competency-based thinking as it is currently understood is ill-adapted to the task of training engineers to possess the innovation mindset necessary to confront sustainable development. The second section offers some suggestions as to how to reformulate competency-based thinking, which we call moving from a restricted competencies paradigm to diversified competencies paradigm, illustrating both the nature of this shift in perspectives and some of the practical implications of undergoing such a shift.

2. COMPETENCY BASED EDUCATION AND THE PROBLEM OF WICKED PROBLEMS

2.1 Competency-based Education

Competency based education is built upon the notion that we can specify, inculcate, and test the skills and competencies required to be counted as competent in a given field (Klingstedt 1972: 7). Within the conceptual framework of a competency-based approach, engineering educators aim to specify the skills that engineering graduates need, and to tailor the training that they receive to make sure that they possess these skills upon graduation. In order to determine these skills engineering schools can address themselves to employers, obtaining information from them concerning engineering jobs and the skills needed to complete them. This vision of education is obviously well-suited to a conception of engineering education in which the expressed objective of engineering schools is satisfying the demands of industry with static and well-known needs. This approach is currently being applied to rethinking engineering education to deal with the challenge of sustainable development (see, for example Wiek et al. 2011). Unfortunately, competency-based approaches, at least as they are currently understood, are poorly adapted to training people to deal with problems like sustainability. The reason for this has to do with the impact of wicked problems like sustainability on our ability to isolate key testable skills.

2.2 Wicked and Tame Problems

The term wicked problem was introduced by Horst Rittel and Melvin Webber. They used this idea to explain why many neat technical solutions to socio-technical problems fail, noting that these problems cannot be solved in the way that ordinary, “tame” scientific problems can be. Tame problems are ones where the problem itself is well and clearly defined, both in terms of the elements concerned and the solutions that might be considered acceptable. Wicked problems, to the contrary, are highly-complex and poorly defined, with their proper formulation itself being subject to controversy. Rittel and Webber list ten characteristics of wicked problems, which unfortunately we will go into here due to time constraints.¹ The essence of any wicked problem is that it has no definitive formulation and no definitive solution.

2.3 Sustainable Development as a Wicked Problem

Sustainable development has often been framed using what Elkington (1999) has called the “triple bottom line”: economy, environment, and society. Framing sustainability as a triplicate balancing act can make it look like a tame problem. Yet let us consider a supposed solution to a sustainability related problem to see how and why the problem is much more wicked than balancing the triple bottom line may make it seem. “Smart” everything seems to be the answer given by many to the current problem of sustainable development. With smart factories, smart agriculture, smart cities and so on, people argue that companies will be able to balance the profit motive with economic and social responsibility. Yet let us look at this answer more closely.

A smart factory can increase efficiency and thus lower costs and reduce waste. This is both economically interesting and ecologically interesting. Given the lowered production costs and increased production flexibility, more consumers can get cheaper access to better products. Thus Industry 4.0 may seem like a win-win-win situation from the point of view of the triple bottom line. Yet if we look at the same phenomenon within a slightly longer time-frame or feedback loop these victories

appear ambiguous. While smart factories can lower the relative environmental burden of continuing on the same path, the flexibility and lower production costs that they promise are likely to stimulate and expand the culture of consumption. It has been noted, for example, that markets do not respond to decreases in the cost of oil by saving their money and consuming less, but rather by taking the money saved and consuming more, thus yielding a net loss in long-term environmental sustainability. While this may not necessarily be an outcome of Industry 4.0, it is certainly a possibility. From a social point of view, the improved quality of social life that will come from access to cheap and high-quality consumer goods may also be accompanied by job losses as human workers are replaced by computerized systems (see MacAfee and Brynjolfsson 2014). Once again, the apparent solution shows itself to raise further problems.

This kind of uncertainty and complexity with respect to possible solutions is characteristic of wicked problems. More to the point, attempting to approach such problems as if they could be solved by neatly balancing an equation actually draws attention away from the real complexity of the problem.

2.3.1 Super Wicked Problems

Sustainability has been classified not only as a wicked problem but as a super-wicked problem by some observers. Levin et al. (2012) add the adjective “super” to denote wicked problems that are also existentially urgent.ⁱⁱ In other words, failure to address sustainability, or addressing it poorly, can lead to collapse. Failing to take sustainability seriously by accepting pseudo-solutions will increase the risk of collapse by stifling or delaying other forms of more adequate action. Pedagogically speaking, the risk is training students who mindlessly believe that they have solved a problem without seeing the additional risks created by their partial solution.

2.4 Solving Super Wicked Problems?

2.4.1 Adequate Solutions

Wicked problems cannot be solved, though they can be approached in ways that are better or worse, more or less sensitive to the complexity of the problem, its gravity, and its difficulty. To say that a problem is a wicked problem does not thus condemn us to nihilism, but to the recognition that one-size-fits-all solutions won't work, and that the success of any solution will only become apparent within the timescale of a long feedback loop. One could say that an adequate solution to the problem of sustainable development would be one that future citizens could look back on and feel that had positively benefitted the becoming of the form of life that they currently enjoy. But they would not see that solution as definitive or without compromises. Any response to a wicked problem will most likely require continual revision through ongoing monitoring and innovation.

2.4.2 Paradigm Shifts?

Generally speaking, wicked problems are open to many different ways of posing, and thus addressing the problem, and sometimes the ability to reformulate problems can be as important as the ability to solve them. Drawing on the philosophy of Thomas Kuhn, we might say that wicked problems are not so much solved, as resolved through a paradigm shift. A paradigm shift would initiate new ways thinking about the same

issues, even if these would be (following Hacking (1983)) “incommensurable,” in the sense that the old problems and paradoxes would no longer matter. Bringing about a paradigm shift in the domain that we currently call sustainable development—for instance, by replacing the triple bottom line with another and more subtle tool for thinking about posing sustainability problems—might also be understood as a key skill.

2.5 Super Wicked Problems as a Problem for Thinking about Testing Competencies

Is it possible to rethink competency-based learning to deal with super wicked problems like sustainability? A first response would have to be no: Testability is at the core of competency-based learning, and the very idea of testing someone’s ability to solve a problem that no one can solve is nonsense. It is equally problematic to think that one can test the ability to find innovative solutions in the same way that one can test the ability to solve sums, or the ability to create problem re-framing paradigm shifts in the way that one deduces a formula from a word problem. Confronted with wicked problems the strategy of isolating a set of key skills is doomed to failure. This lack of fit between typical approaches to competency-based learning and super wicked problems like sustainability is clearly recognized by Lonngren (2017). She makes a serious attempt to adapt the competency-based approach to wicked problems by focusing on testing the ability to “address” wicked problems rather than solve them. According to her, addressing capacities can be assessed (though only qualitatively and subjectively). She thus feels that we can establish a limited set of “assessment competencies.” This view is flawed, however, as any ability to assess a problem assumes a point of view on that problem. But what paradigm shift is, is an innovative viewpoint on a problem, and thus a new range of assessment competencies. This brings us to the hard truth about wicked problems: whenever we try to find a limited and simple set of criteria for solving them we end up obscuring the complexity of the problem and impoverishing our student’s by selling them skills that only pseudo-resolve pseudo-problems.

3. FROM RESTRICTED COMPETENCES TO DIVERSE COMPETENCES

Our response to this frustration is to shift our thinking. Rather than asking which approaches are necessary for all students, we can ask how we can form more approaches, skills, and competences among all of our students, without necessarily demanding of ourselves that we know which competences these will be in advance. I call this perspectival shift the movement from the restricted competences paradigm to the diverse competences paradigm. Within the diversification of competences approach to competency-based education, the aim is not to inculcate a limited set of key competences, but to discover how to foster as many, and as different, competences as possible among the students in any given engineering program.

Here are some reasons why such a shift might make sense from the point of view of reforming engineering education to deal with a complex problem like sustainability. The more assessment competences applied to any given wicked problem the better. Actors approaching the same problem with different competences will propose different solutions, the combinations between which will almost assuredly yield further innovations. Different competence portfolios will also yield different ways of framing problems, and so will also heighten the likelihood of paradigm shifts. All of this has been demonstrated both via computer models and empirical experience by Page (2004).

Admittedly, this vision of diversification, which aims to increase competence-diversity rather than to reduce competence-diversity towards the expression of a restricted set of recognized key competences, obviously calls for a significant complexification of our reflections on the engineering curriculum, and some revisions in the ways in which we might imagine the future of engineering practice.

3.1 Diverse Competences and Diversity Bonuses

Within the restricted competences approach, one defines a singular image of the engineer and delimits a single set of relevant and well-defined competences. The diverse competences model takes as its paradigm case a collective that will work together to accomplish things that none of them could do individually. A team-based approach to problem-solving is something that research has shown to be a major driver of innovation—providing it is carried out correctly (Sawyer 2007). As Page (2018) explains, cognitively diverse groups benefit from a “diversity bonus” when dealing with highly complex problems. What he means by this is that diverse groups are able to find more perceptive and innovative solutions to complex problems than either individuals or homogenous groups of individually highly competent individuals because diverse collectives can see and do different things by using their differences. The explanation for this phenomenon is that meaningful competence diversity amounts to the possession of diverse perspectives, knowledge bases, and problem-solving heuristics which have been shown to be the key ingredients in innovative teams (Livermore 2016). That said, the diverse competences approach could be applied at an individual level, with schools aiming to foster as many competences as possible. This is one of the possible outcomes of a making-centered curriculum such as found at Olin College, for the openness of creative learning allows each student to develop situation-specific competences that may be other than those anticipated by instructors.

3.2 Meaningful Diversity

If the aim of sustainability-driven engineering education is the diversification of competences for the augmentation of wicked problem-confronting capacity, it is nevertheless true that not just any diversity and difference is meaningful. Some differences are what might be called superficial, while others might be classified as irrelevant. Complexity scholars such as Wolfram (2002) situate complexity between simplicity and the mangle of randomness, with a mangle offering—in opposition to a complex system—no apparent structure. In this light, it is useful to consider what might be a meaningful basis for thinking about how to generate complexification and diversification within a curriculum as opposed mere mangling. One obvious candidate for fostering competence diversification is input diversity. It is likely that upon hearing the word diversity one imagines differences like gender, race, class, and physical ability. Yet it can be argued that input diversity that is not coupled with a concerted attempt to stimulate output diversity will not yield meaningful differences. To the contrary, as diversity scholars have argued, one size-fits all approaches to education often yield both less diversity and less functional teams as minority students strive to repress their differences. Of course, input diversity does contribute to output diversity, but only if effort is made to foster and value differences that make a difference—to promote inclusion, which is to say both an appreciation for and stimulation of competence diversity.

3.3. Multiple Intelligences as a Diversification Principle

The benefit of diversity for problem solving comes from the fact that members of diverse groups have what Page (2018) has described as a diversity of “cognitive repertoire.” Abstractly then, it makes sense to make differing cognitive types the foundation for the competence diversification of engineering education. This is not because this is the only source of difference—but because one cannot include ethnic heritage, sexual persuasion, or other sources of upstream diversity within a curriculum.

By cognitive types we are referring to what Howard Gardner (2006) has described as “multiple intelligences,” which on his categorization include eight diverse kinds of minds: linguistic, logico-mathematical, spatial, bodily, musical, interpersonal, intrapersonal, and naturalistic. The traditional vision of the engineer, and almost all lists of engineering competences currently proposed, primarily focus on logico-mathematical competences. However, at the highly-innovative Olin College, Gardner’s theory of multiple intelligence has been adapted (and streamlined) to yield what they call the “whole” engineer, who knows how to harness the Analytical mind, the Design mind, the Linguistic mind, the People mind, the Body mind, and the Mindful mind (Goldberg and Sommerville, 2014). The aim of a diversifying curriculum would be to help each student go farther in their expansion into the kind of mindedness that fits them best, using problem-based approaches adapted to exploring and expanding their specific kinds of mindedness.

Future engineers would thus possess not only a technical specialization, but also a high degree of cognitive individualization. Such diversification can only function, of course, within the context of a standing and broad-based commitment to diversity and inclusion extending from schools into industry.

3.4 Diversity as Problem

Obviously, aiming to increase the diversity of the cognitive portfolios available within the engineering profession will create challenges at many levels. Diverse teams are sometimes conflictual and poorly-functioning (Livermore 2016). Engineers will need to develop the habit of working collectively, and will need to be constantly ready to learn new strategies to deal with the challenge of engaging with and including their diverse team mates, including constantly attempting to understand their own biases (Mor Barak 2015). Inclusivity here does not merely mean that varying kinds of cognitive profiles are present within teams, but also that differences are valued and permitted to be expressed within the collective output. Minorities often self-censure of their knowledge claims (submitting to what Fricker (2007) has described as “hermeneutical injustice”) a practice that will tend to dilute the diversity bonuses available to any group. Understanding how to train diverse kinds of engineers to engage in inclusive collective work while further discovering and expressing their diversity will require research, but it is above all a matter of practice, itself a wicked problem.

3.5 Complexity as a Problem

Yet a challenge to any diversification of the curriculum integrating the stimulation of diversity within a single course or institution. This is a technical problem relating to the means of teaching. The traditional technologies associated with the development of the curriculum—teacher-centered learning, standard text books and the fixed list of

required classes which determine the planning of the hours of the school day—are hardly well adapted to generating cognitive diversity. New technologies and approaches, such as adaptive software, project-based learning, and other alternative and student-centered methodologies can be employed to make possible the complexification and diversification of the curriculum without excessively charging already limited institutional budgets.

3.5.1 Project-based Learning

Project-based learning is a low-tech alternative teaching method that is well suited to accommodating cognitive difference and fostering competence diversification. Team projects can be organized in such a way that each member of the team is able to learn to best contribute to the overall task by developing specific skills, knowledges, and viewpoints, learning through doing and expanding outward their initial difference through practice. Within the context of educating for sustainable development, it would obviously be desirable if these projects were sustainability-oriented. A possible weakness of this approach is the fact that improperly guided diverse teams may well function in ways that reinstate existing hierarchies relative to the contributions of diverse viewpoints. A coaching approach will thus be required to aid students to look for the best ways of diversifying their own skills and resisting falling into Irving Janis (1972) has called groupthink.

3.5.2 Smart Learning Approaches

Adaptive artificial-intelligence driven learning tools are able to produce student-centered and difference-driven learning experiences. What advanced versions of such tools might concretely look like remains to be seen, but just as Google and other companies use predictive algorithms to seduce consumers to purchase new goods based upon their past purchases and searches, to too can learning tools propose new lessons and materials to students based upon their aptitudes and past interests. Clayton Christensen (2011) has written about the ways in which innovative forms of computer-based learning can be used to adapt pedagogy to different kinds of learners and learning styles, and differential forms of learner-adapted technologies can be developed to cater to and maximally stimulate both different kinds of learners and different forms of cognitive diversity.

3.6 Evaluating Diverse Competences

As we have stated earlier, evaluation and evaluability are key elements in competency-based approaches to education. While a limited skill set permits standardized evaluations, multiplying the skills and knowledges acquired by students poses problems for those aiming to put into place evaluative frameworks. Among other things, a fully diversified approach to curriculum would mean that the knowledges possessed by learners would be different from those possessed by their assessors. We have already touched on the fact that Lonngren advocates using more-less frameworks rather than binary frameworks for the assessment of wicked problem assessment skills. She is probably right to recognize that diversification will yield more qualitative than quantitative approaches to assessment.

One way of thinking about evaluation would be to focus not on the skills but on the qualities of the outputs of collective projects involving diverse actors. While the evaluation of made objects is a matter calling for holistic appreciations and individual

judgment, it would be unfair to suggest that making-oriented education abandons evaluability. Slightly differently, students working with adaptive smart learning systems could be evaluated not on their specific outputs but on depth of the path that they have travelled. In both cases, the acquired competences may remain a black box to the outside observer. This is no problem, except insofar as it inflicts wounds upon educator's pretensions that total knowledge of a subject is the basis for their authority.

4. CONCLUSIONS

If you are a handyman who has received a call from a client stating that they have a problem, you might spend your time thinking about which limited set of tools you want to bring with you, or to the contrary, you might invest your effort in finding ways to bring a greater variety of tools. If tools and engineers are not exactly equivalent, our suggestion is that many theorists of engineering education opt for the first approach, when we really ought to be opting for the second.

To many, the call for diversity as an approach to dealing with sustainable development that is at the core of this paper may seem reassuring, but the conclusions and general argument may seem radical, disruptive, even disturbing. This text has set out rethink competency-based approaches to engineering education as if meeting the challenge of sustainability is more important than maintaining institutional norms. It has willfully embraced the idea that radical new technologies can reconfigure teaching and learning, heretically suggesting that the teacher can be displaced from the all-knowing center of the learning experience to the position of an accessory or complement to interactions with other learners and smart technologies. From an institutional standpoint these arguments imply that no one administrator will be able to oversee and understand all of the competences being developed within that institution, and that the augmentation of diverse competences, rather than the delimitation of a small set of desired competences, is a good thing. Avowedly, part of the radicality of this proposal is the changes that it demands in the images of the engineer and the educator of engineers. According to the vision presented above, it will no longer make sense to speak of one competent engineer but only of diverse engineers with diverse competences, with the plurality of the profession taken in the strongest sense, given that the practice of problem solving that some might say is the heart of the engineer's *métier* is here reconceived of as a necessarily collective process.

While the very radicality of these propositions doubtless condemns them to marginality, this communication should be counted successful if it is at very least thought provoking.

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ⁱ The list that is furnished by Ritter and Webber is as follows:

- 1) Wicked problems have no definitive formulation
- 2) Wicked problems have no ends to the causal chains—'no stopping rule'
- 3) Wicked problems do not have 'true-false' solutions, rather 'good-bad' ones
- 4) Wicked problems offer no 'immediate' or 'ultimate' tests for a solution
- 5) Wicked problems mean that every attempt at a solution is consequential
- 6) Wicked problems do not have an 'exhaustively describable' set or series of solutions
- 7) Every wicked problem is unique—having at least one 'distinguishing property that is of overriding importance'
- 8) Every wicked problem points to another wicked problem—each a symptom of another
- 9) Wicked-problem discrepancies can be explained in multiple ways—each 'choice of explanation determines the nature of the problem's resolution'
- 10) Wicked problems pose particular problems for those aiming to resolve them—exempting them from the right to be wrong.

- ⁱⁱ
- 1.) time is running out
 - 2.) those who cause the problem also seek to provide a solution
 - 3.) the central authority needed to address them is weak or non-existent
 - 4.) irrational discounting occurs that pushes responses into the future