

The Potential Virtues of Wicked Problems for Education

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We offer a contribution to a theory of transdisciplinary curriculum based in empirical research of an undergraduate mathematics course in quantitative literacy. By organizing around contexts and developing open, semester-long projects, this course blurred disciplinary boundaries. Fortunately, ignoring debates about where mathematics ends and these contexts begin is well-suited for the goals of general undergraduate courses. We found that the language of transdisciplinary and wicked problems fitted our experiences designing, teaching, and studying the course. We share selected empirical findings, then develop a transdisciplinary curriculum theory for wicked problems.

Keywords: wicked problems, transdisciplinary education, curriculum, quantitative literacy

This is the first human generation in which the majority will live in crowded cities, whose actions will flood low-lying islands and whose rate of resource use exceeds 2.5 times the production capacity of the planet (Melkert and Vox, 2008). Well-founded projections suggest that future supplies of the air we need to breathe, the water to drink and the food to eat are in doubt. (Schneider et al., 2007 as cited in Brown, Deane, Harris, & Russell, 2010, p. 3).

It seems as though some problems are tame, such as factoring a quadratic equation, traversing a maze, and solving the tower of Hanoi puzzle. But problems of importance... are invariably 'wicked.' (Coyne, 2005, pp. 5-6)

The first excerpt above is the opening paragraph of a book, *Tackling Wicked Problems* (Brown et al., 2010), which focuses on uniting people across and outside of disciplines to confront the global problems that affect us all. In the book, scholars argued that this particular class of problems requires *transdisciplinary inquiry*--fusion of knowledges across and outside of disciplinary boundaries. Transdisciplinary approaches create knowledge that "is more than the sum of its disciplinary components" (Lawrence, 2010, p. 19).

The *wicked problems* at the center of this transdisciplinary inquiry require imaginative approaches because they cannot be (or at least, have not been) fully resolved through disciplinary techniques. In the second quotation above, Coyne (2005) illustrated wicked problems by contrasting them with tame problems. Coyne used these three examples--factoring, navigating a maze, and the tower of Hanoi puzzle--which inadvertently criticized the prevalence of tame problems in mathematics education. The tame problem examples he chose subtly posed a challenge to mathematics education to consider different problems, called "wicked."

How might we, mathematics educators, react? In this paper, we produce a theoretical report grounded in an empirical study of a quantitative literacy (QL) course which involved a focus on wicked problems. The theoretical perspective is a transdisciplinary curricular theory focused on education about wicked problems. We found that such an approach can involve at least four things: a context-based curricular organization, a blurring or erasure of disciplinary boundaries to

classroom activity, opportunities to engage in open problematizing of the world, and a repositioning of the teacher relative to students.

Transdisciplinary Education for Wicked Problems

Rittel and Webber (1973) first conceptualized wicked problems in design and planning. They argued that there are ten distinguishing characteristics of wicked problems:

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rules.
3. Solutions to wicked problems are not true or false, but good or bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a ‘one-shot operation’; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of possible solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem’s resolution.
10. The planner has no right to be wrong.

Wicked problems have been conceptualized within many fields, including: environmental studies (e.g., Kreuter, De Rosa, Howze, & Baldwin, 2004), political science and public policy (e.g., Head, 2008), public health (e.g., Blackman et al., 2006), public risk and defense (e.g., Ritchey, 2001), and economics (e.g., Batie, 2008). The move to consider work in their fields as wicked problems generally emerged alongside recognition of limitations of attempts to quantify complexity. Ritchey (2001) claimed, “if you work with long-term social, commercial, or organizational planning – or any type of policy planning that impacts *people* – then you’ve got *wicked problems* (p. 1). The presence of wicked problems can be signified by a sense of reactivity, where after attempting resolution, the problem transforms and “fight[s] back when you try to do something” (Ritchey, 2001, p. 1).

Studying complex wicked problems, therefore, poses a challenge to disciplinary approaches to knowledge; in response, transdisciplinary approaches “step outside the limiting frames and methods of phenomenon-specific disciplines” (Davis, 2008, p. 55). The transdisciplinary approach mirrors the collective nature of wicked problems and values not only the multiplicity of knowledges from different disciplines, but also their tapestry (Lawrence, 2008).

Transdisciplinary approaches involve redrawing the boundaries of inquiry (to the extent possible) *around the problems themselves*, to ask what disciplines and their unifications can contribute to addressing and resolving a problem, rather than whether a problem belongs inside a discipline.

Transdisciplinary Wicked Problems and Quantitative Literacy (QL)

In mathematics education, Vacher (2011; 2017) has begun to argue that QL is transdisciplinary. His claim ultimately hinges on the fact that people from different disciplines have used QL or numeracy as terminology to connect the quantitative to their fields. Our approach to transdisciplinary is different in that we are decentering the disciplines, and instead

focusing on wicked problems. As a result, the early empirical underpinnings of this transdisciplinary curriculum theory emerge from an undergraduate QL course not centered solely on learning mathematics and statistics; instead, the course is centered on exploring what mathematics and statistics might offer us while we learn about *contexts and wicked problems within them*. Of course, the course certainly did involve students learning significant mathematics and statistics, but that was not the primary organizational element.

This QL classroom was located at a large Midwestern university--a predominantly white institution located in what is often described as a “college-town.” The studied course emerged from institutional efforts to provide multiple routes to fulfilling the university’s general mathematics degree requirement. This course was organized around three different context-based modules: *The World and Its Peoples*, organized around the choices and power involved in counting people and quantifying the world; *Numbers and Media*, designed around the flexibility of numbers as socially constructed, rhetorical, subjected, and powerful; and *Health and Risk*, centered on considering the quantification in health and risk and its implications on fear and safety narratives. In the next section, we used examples from students’ work to further illuminate characteristics of wicked problems. We pulled the examples from a larger study of students’ course projects (Craig, 2017). All names are pseudonyms.

Examples of Wicked Problems Characteristics

The students chose a wide variety of issues to study, but formulating the particular problem or set of problems was challenging. Many students asked about the suitability of a particular topic for this project. Upon first impression, many students’ topic choices had developed ideas around problems of massive scope (e.g., racism, climate change). Despite students completing the same project phases, their work was unique content because they focused on different problems and formulated similar problems differently.

(Characteristic #7) Every wicked problem is essentially unique.

We begin our exploration of wicked problem characteristics with Characteristic #7 to share some students’ project topics, found in Table 1. The range project topics illustrates how wicked problems are not confined to any disciplinary boundary, including mathematics. Further, the list also suggests how all disciplines, including mathematics, are relevant to considering wicked problems.

Table 1. Selected Student Projects Titles and Descriptions

Title	Description
Censorship	Internet censorship policies and histories across countries
Climate Change	Looking at the impacts of polar ice shifts on climate from a religious perspective
Do Schools Kill Creativity?	Budget cuts to arts and humanities programs in K-12 public schools in the United States
Domestic Violence	The perpetual cycle of domestic violence across generations
Drug Abuses and Overdoses	The prevalence of heroin abuse in specific cities across the United States
Gun Violence	Advocating ways to avoid gun violence, specifically preventative learning about guns

Impact of Big Money on Politics	The results of the Citizens United court decision on money entering politics
Overpopulation	The effects of a one-child policy on China and the persistence of problems of resource use
People of Color in Media	The erasure of entertainment and media achievements of actors of color
Recycling Practices	Cross-country analysis of recycling practices and constraints on recycling
Representation of Women in Media	The disparities in gender representation in political news reporting
Stigmas around Mental Illness	How different cultures respond to depression and stigmatize the illness

(Characteristic #1) There is No Definitive Formulation of a Wicked Problem

Another issue that internet censorship is tied to is that sometimes internet censorship can be a good thing. For example, I don't think it is okay for people to be posting pro-terrorist webpages, or terrorist recruitment forms online. If it really is a threat to national security, then I believe that the government has a right to restrict that. (Matt, Phase 2, Media Synthesis)

Matt confronted the challenge of formulating what the problem of censorship entirely involved. Rittel and Weber (1973) stated that “the formulation of a wicked problem *is* the problem!” (p. 137). To formulate a wicked problem involves establishing a discrepancy between what *is* and what *should be*. But there are plural perspectives on both what is and what should be, and therefore multiple formulations of the problems we face.

(Characteristic #2) Wicked Problems Have No Stopping Rules

The one child policy was published to limit people to have only one child. This stopped the growth of population. And people's life changed a lot from this. Then, population aging became another issue for China. Population aging hurts the economy and the government decides to end the one child policy. The new policy is “One Couple, Two Children. (Leilei, Phase 2, Media Synthesis)

Because wicked problems have no stopping rules, that implies they have a history. Students engaged with the histories of these complex wicked problems through media analyses and syntheses, which usually included their own formulation of the problem and explanation for the cause. The reintroduction of the initial problems underscored the complexity and fluidity of these projects. The challenges involved in testing solutions to wicked problems are underscored by the idea that those solutions cannot be evaluated in the same way that tame problems can.

(Characteristic #3) Solutions to Wicked Problems are Not True or False, but Good or Bad

I think we can measure improvement with the issue of the lack of diversity by continuing to take data on how diverse film characters are in general. But, by how many women are directing mainstream? People of color? Who are running these networks? Who are writing these shows? Orange is the New Black has one of the most diverse casts on

television right now. The writing room is mostly women, but no people of color. Do we chalk this up to a win anyway? (Aisha, Phase 4, Written Reflection)

Aisha's reflection further complexified the relationship between mathematics and statistics as disciplines and the resolution of wicked problems. She recognized the limitations of mathematics in determining the quality of a solution. The transdisciplinary reasoning emerged from how open problematizing, as Smith (1997) predicted, burst the boundaries of mathematics curriculum.

(Characteristic #4) There is No Immediate and No Ultimate Test of a Solution to a Wicked Problem

I think it's interesting that the world measures depression by suicide count. I don't know how accurate I feel that is but it's interesting and I wish that we could change it. *But how do you measure depression? Through chronic, manic, and other forms of breakdown or do we not measure it by severity and simply mush it all together? It's difficult to measure something that can't be seen.* (Beth, Phase 4, Written Reflection, emphasis added)

Beth summarized how wicked problems change what it means to do problem solving. The choices of what to measure, how, and when, are political and aligned with particular formulations and particular explanations of a wicked problem discrepancy (Best, 2008). Quantitative methods and information cannot provide evidence of improvement on a wicked problem, unless situated within a particular formulation of the problem. Within the boundaries of mathematical problem solving, this deeper consideration of how to engage quantitative methods involves traversing disciplinary boundaries for other information.

(Characteristic #5) Every Solution to a Wicked Problem is a 'One-Shot Operation'; Because There is no Opportunity to Learn by Trial-and-Error, Every Attempt Counts Significantly

He brings up the fact that there are so many murders in Central America and Mexico and other parts of the world, prisons packed, the global black market is estimated at 3 hundred billion a year, *all due to the war on drugs. Yet more people are using drugs than there ever was before.* (Diana, Phase 2, Media Analysis, emphasis added)

Diana's analysis of a piece of media reflects something critical about the urgency of these wicked problems. Despite this course being labeled mathematics, many forms of reasoning were salient. Specifically, quantitative methodologists would have very particular and technical strategies for determining the effects of the war on drugs (not the least of which would be formulating what that means). At the same time, there is very serious moral, social, historical, psychological, and intuitive reasoning involved in my students' projects.

(Characteristic #6) Wicked Problems Do Not Have an Enumerable (Or an Exhaustively Describable) Set of Possible Solutions, Nor is There a Well-Described Set of Permissible Operations that May Be Incorporated into the Plan

I'm not entirely sure what the plot of the story that I am hoping to tell is but I know *that I want to talk about the collective solution to the problem from multiple sources...* community awareness, education on certain matters revolving around mental health, and acceptance are the ideal ways to combat more easily preventable mental health problems

or at least to lessen the effects of the problem. (Beth, Phase 3, Infographic Check-in, emphasis added)

This aspect of wicked problems came out the most in a class check-in where I asked students to report the plot of the infographic they were creating for the third phase of the project. There are no limits on what can be included in resolving a wicked problem, and the acceptance of multiple forms of data and engagement of multiple forms of reasoning across and outside of disciplinary boundaries is central.

(Characteristic #8) Every Wicked Problem Can Be Considered to Be a Symptom of Another Problem

After doing the research, I found the issue is not only too many people, but also pollution, land, resources and other issues. (Leilei, Phase 4, Written Reflection)

Leilei produced a project on China's One-Child Policy and concluded that overpopulation itself is an amalgam of other interlocking problems. Although the first phase of the project was the explicit time when students formulated their topic, the challenges to problematizing wicked problems persisted through complexity. I had five students make significant changes to their topics during the second phase of the project, as they clarified their own interests, but all students reformulated their problems at some point during the course.

(Characteristic #9) The Existence of a Discrepancy Representing a Wicked Problem Can Be Explained in Numerous Ways. The Choice of Explanation Determines the Nature of the Problem's Resolution

There are a few different issues revolving around the stigma that exists around mental illness; the first being that people sometimes avoid or bully those suffering from mental illness just due to their differences, the next is that mental illness is often misrepresented in the media, those suffering from mental illness in television shows or movies are almost always depicted as some sort of antagonist, murderer, or criminal. (Beth, Phase 2, Media Synthesis)

Beth's project on mental illness evolved into an investigation of cultural differences in identifying and treating mental illness. She focused on a discrepancy between perceptions of mental illness taking the form of stigma and the realities of people suffering from mental illness. She had different explanations for that discrepancy which she explored during her project.

(Characteristic #10) The Planner Has No Right To Be Wrong

...In 2014 it is estimated that at least 6,800 overdose deaths occurred in the European Union. In Oceania, which includes Australia and New Zealand, there were 1,700 and 2,100 drug related deaths in 2013. In Scotland there were 613 drug related deaths in 2014. In South America, the Caribbean and Central America reported between 4,900 and 10,900 drug related deaths in 2013. In the United States, overdose deaths from opioids, including prescription opioids and heroin, have nearly quadrupled since 1999. Overdoses involving opioids killed more than 28,000 people in 2014. During 2014, a total of 47,055 drug overdose deaths occurred in the United States. *These statistics make it known that*

the use of drugs is a very serious issue that needs to be fixed somehow. (Diana, Phase 2, Media Synthesis, emphasis added)

Diana's project on the opioid epidemic developed out of her hometown struggling with drug addiction. Although Diana herself formulated the problem in a particular way with a particular resolution – “our drug policies care more about criminalization over health and this has to be changed” (Diana, Phase 2, Media Analysis) – she explicitly noted the seriousness, urgency, and responsibility for policy planners to act.

Discussion

Our purpose for sharing these examples of how wicked problem characteristics manifested in students' course projects was to give life to the characteristics, rather than leave them as strictly theoretical. Craig (2017) explored three themes that emerged from a deeper analysis of the course projects, transdisciplinary, complexity, and democratic openness. Here, we focused on transdisciplinary to begin developing a curriculum theory. A *transdisciplinary curriculum theory for wicked problems* both connects with and diverges from disciplinary education in mathematics or statistics. On one hand, the openness of transdisciplinary inquiry is fully inclusive to all disciplines, therefore, mathematics and statistics play indispensable roles. On the other hand, exploring wicked problems within disciplinary boundaries necessarily excludes important considerations and leaves resolutions more fragile, incomplete, and possibly counterproductive.

For wicked problems where boundaries are elusive (or impossible) to draw, the inquiry process should be inclusive. All knowledges are relevant and applicable to resolving wicked problems, and transdisciplinarity “is created by including the personal, the local and the strategic, as well as specialized contributions to knowledge” (Brown et al., 2010, p. 4). This lack of boundaries is conducive to a *transdisciplinary imagination* (Brown et al., 2010). In the transdisciplinary imagination are attempts “to generate fundamentally new conceptual frameworks, hypotheses, theories, models, and methodological applications that *transcend* their disciplinary origins” (Hall et al., 2012, p. 416, emphasis in original).

Wicked problems facing the world regarding sustainability are staggering in scope, and elusive. Further, evidence increasingly suggests that addressing sustainability questions necessarily involves addressing myriad social injustices and complex economic relationships (Peterson, 2016). Nearly two decades ago, education for wicked problems was “taken seriously by no one, even if they are included with some regularity in official curriculum documents” (Parker, Ninomiya, & Cogan, 1999, p. 119). Serious consideration of these wicked problems as justifiable school curriculum remains uncommon. Although some argue we prepare students to be wicked problem solvers by becoming expert tame problem solvers, we still generally avoid these problems during schooling in favor of self-contained and sanitized word problems, particularly in mathematics education.

That wicked problems theory emerged from design theory is fitting for considering curriculum theory. Designing curriculum involves reactive, complex, and transdisciplinary students, situated among reactive, complex, and transdisciplinary social institutions and wicked problems. Perhaps curriculum design is a wicked problem, without final resolution. But, what right do we have to be wrong about education? We share responsibility for the social problems caused by and embedded in how schools, curricula, assessments, and teaching are designed and planned (Butin, 2002).

References

- Batie, S. S. (2008). Wicked problems and applied economics. *American Journal of Agricultural Economics*, 90(5), 1176-1191. <http://dx.doi.org/10.1111/j.1467-8276.2008.01202.x>
- Best, J. (2008). Birds—dead and deadly: Why numeracy needs to address social construction. *Numeracy*, 1(1), 6. <http://dx.doi.org/10.5038/1936-4660.1.1.6>
- Blackman, T., Greene, A., Hunter, D. J., McKee, L., Elliott, E., Harrington, B., ... Williams, G. (2006). Performance assessment and wicked problems: The case of health inequalities. *Public Policy and Administration*, 21(2), 66–80. <http://dx.doi.org/10.1177/095207670602100206>
- Brown, V. A., Harris, J. A., & Russell, J. Y. (2010). *Tackling wicked problems through the transdisciplinary imagination*. Earthscan.
- Butin, D. W. (2002). This ain't talk therapy: Problematizing and extending anti-oppressive education. *Educational Researcher*, 31(3), 14–16. <http://doi.org/10.1002/jwmg.567>
- Coyne, R. (2005). Wicked problems revisited. *Design studies*, 26(1), 5–17. <http://dx.doi.org/10.1016/j.destud.2004.06.005>
- Craig, J. C. (2017). Real fantasies in mathematics education: Numeracy, quantitative reasoners, and transdisciplinary wicked problems (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No. 10621502)
- Davis, B. (2008). Complexity and education: Vital simultaneities. *Educational Philosophy and Theory*, 40(1), 50-65. <http://dx.doi.org/10.1111/j.1469-5812.2007.00402.x>
- Hall, K. L., Vogel, A. L., Stipelman, B. A., Stokols, D., Morgan, G., & Gehlert, S. (2012). A four-phase model of transdisciplinary team-based research: Goals, team processes, and strategies. *Translational Behavioral Medicine*, 2(4), 415–430. <http://dx.doi.org/10.1007/s13142-012-0167-y>
- Head, B. W. (2008). Wicked problems in public policy. *Public Policy*, 3(2), 101–118. <http://dx.doi.org/10.1128/MCB.00567-07>
- Kreuter, M. W., De Rosa, C., Howze, E. H., & Baldwin, G. T. (2004). Understanding wicked problems: A key to advancing environmental health promotion. *Health Education & Behavior*, 31(4), 441–454. <http://dx.doi.org/10.1177/1090198104265597>
- Lawrence, R. J. (2010). Deciphering interdisciplinary and transdisciplinary contributions. *Transdisciplinary Journal of Engineering & Science*, 1(1), 111–116. Retrieved from <http://www.atlas-journal.org/>
- Ritchey, T. (2011). *Wicked problems—social messes: Decision support modelling with morphological analysis*. Sweden: Springer.
- Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, 4(2), 155–169. <http://dx.doi.org/10.1007/BF01405730>
- Parker, W. C., Ninomiya, A., & Cogan, J. (1999). Educating world citizens: Toward multinational curriculum development. *American Educational Research Journal*, 36(2), 117–145. <http://dx.doi.org/10.3102/00028312036002117>
- Peterson, H. (2009). Transformational supply chains and the ‘wicked problem’ of sustainability: aligning knowledge, innovation, entrepreneurship, and leadership. *Journal on Chain and Network Science*, 9(2), 71–82. <http://dx.doi.org/10.3920/JCNS2009.x178>
- Smith, J. P. (1997). Problems with problematizing mathematics: A reply to Hiebert et al. *Educational Researcher*, 26(2), 22–24. <http://dx.doi.org/10.3102/0013189X026002022>
- Vacher, H. L. (2011). A LEAP forward for quantitative literacy. *Numeracy*, 4(2), 1. <http://dx.doi.org/10.5038/1936-4660.4.2.1>

Vacher, H. L. (2017). Ten Years, Twenty Issues, and Two Hundred Papers of Numeracy: Toward International Reach and Transdisciplinary Utility. *Numeracy*, 10(2), 1.
<http://dx.doi.org/10.5038/1936-4660.10.2.1>