Philosophy and the Faces of Abstract Mathematics

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Several years ago, while teaching middle and high school mathematics at a small progressive school in upstate New York, I was asked to evaluate and reconceptualize the school's approach to teaching mathematics. From its inception in the early 1960s, the school had prided itself on its progressive ideals. It was child-centered, committed to both project-based learning and to the social and emotional development of children, and a place where independent and critical thinking was highly valued. Yet, it was clear that our mathematics program was not delivering results in line with our expectations. Academically, our students were not low achievers. Yet, to our dismay, very few of our middle and high school students actually liked their mathematics studies.

In writing up my observations of student attitudes, I offered what I termed the "Students' Six Truths of Mathematics":

1. Math is boring.
2. Math is useless.
3. Math is about getting the answer.
4. Math is about memorizing the rules.
5. Math fries my brain.
6. Math proves that I'm stupid.

These statements were not conjectures or inferences based on body language, performance, or general impressions. Rather, since I was fortunate enough to work in an environment where students were encouraged to freely express their feelings about their school experiences, these were statements that I often heard in class. And they were quite an indictment of my teaching as well as those teaching the lower grades. Needless to say, what ensued involved serious soul-searching and attempts at extensive change.

While this experience with negative attitudes toward mathematics involved a relatively small number of students, substantial empirical data suggests that similar attitudes are widespread, particularly as students move through high school (Middleton & Spanias, 1999; National Center for Education Statistics, 2001). Quite disturbing is the finding that students with the highest educational aspirations maintain the most negative attitudes (Wilkins & Ma, 2003). As noted by Middleton and Spanias, "the problem is considered important enough for the National Council of Teachers of Mathematics (NCTM) to place the motivational domains *Learning to value mathematics and Becoming confident in one's own ability* as two of its foremost goals for students" (1999, p. 65). Clearly, the issue has received significant attention.

Unfortunately, mainstream proposals to improve attitudes toward mathematics learning are often too quick to stress the intractability of student disposition and motivation. A case in point is the high profile *Foundations for Success: The Final Report of the National Mathematics Advisory Panel* (NMAP, 2008). The NMAP report offers dozens of empirically based recommendations for improving mathematics learning. Foremost among them is the suggestion of the task group on learning processes to focus on influencing student goals and beliefs about learning. This manifests in vague recommendations to change the "educational environment" to help children adopt "mastery goals" and learn to value effort over ability. While there is brief mention about offering more diverse, meaningful, and challenging tasks, there is little elaboration of what would constitute such tasks in the upper grades. Indeed, the task group concludes with a curious qualification to the possibility of significantly changing attitudes. They state:

> Intrinsic motivation declines across grades, especially in mathematics and the sciences, as material becomes increasingly complex and as instructional formats change. *The complexity of the material being learned reflects demands of a modern workforce that may not be fully reconcilable with intrinsic motivation.* At the same time, correlational evidence suggests that the education environment can influence students' intrinsic motivation to learn in later grades. (pp. 4-17, emphasis is mine)

Clearly, though the task group expects that some of its recommendations hold promise for improving student motivation, it simultaneously puts a damper on expectations. Specifically, the statement suggests that the complexity of the subject matter itself does not inspire a desire to learn. Educators can both tweak the curriculum and enlighten students to the impact of effort on learning, but in the end, abstract mathematics – the mathematics of the college preparatory sequence – is not really all that interesting. Rather, the task group statement reinforces what many educators and parents believe – that high school mathematics is, at its core, a required credential for higher education or a needed skill for the job market (Roschelle, et al., 2008).

I refuse to buy into such a view, and find the speculative nature of the italicized portion of the task group statement particularly distressing. Instead of exploring the possibility that the problem rests with mathematics pedagogy, the task group recommends that we ask students to expend additional effort on tasks that they find inherently distasteful, offering the promise of higher grades and future economic benefit. This prompts the question why students should put out that effort, why college prep mathematics is worthy of a mastery goal. While I agree that much of the college prep math sequence is difficult to master, I do not believe that the subject matter forms the crux of the problem. Rather, as the Six Truths suggest, the issue is one of perceived meaning. That is, students perceive the study of abstract mathematics to be meaningless, unconnected to the world, and of little personal relevance. This is not to say that students do not know, or are not shown, how mathematics connects to all sorts of domains. Rather, students do not feel the import of such knowledge. They cannot conceptualize how binomial factoring and quadratic equations translate to the world and their lives. They cannot bridge the gap between their experience with mathematics, and what they have been told about its place in the world. In short, unlike other arts and sciences, they perceive abstract mathematics as sitting in a void. Under such conditions, it is no wonder that students lack the intrinsic motivation to engage the domain.

If this is indeed the case, we ought to focus on providing meaningful mathematical experiences to high school students. As such, we need to connect this abstract and seemingly insular activity to the world of the student. Thus, in the remainder of this paper, I would like to do two things. First, I want to substantiate the claim that meaningful experience is causally tied to action. To this end, I will present and analyze Hubert Dreyfus and Sean Kelly's theory of "Shining," a theory of action that postulates a causal path from meaningful experience to intrinsic motivation, and finally to "care-ful" or "effort-ful" action – precisely the path that would address the problem of motivation in high school mathematics. Second, I shall argue that engaging students in philosophical issues related to mathematics connects abstract mathematics to the world, helping students *feel* the relevance of the domain. Taken together, these claims suggest that philosophical engagement with mathematics can help students develop a more positive attitude toward the college prep math sequence.

Shining

In their surprising best-seller, *All Things Shining*, Hubert Dreyfus and Sean Kelly (2011) address the existential dilemma of meaningful action in a secular world. Specifically, they attempt to show that contemporary nihilism can be avoided by abandoning the belief in autonomous action. The book describes the evolution of the conditions for contemporary nihilism through a reading of various classic Western texts beginning with Homer's Odyssey and ending with Moby Dick. As the argument goes, the polytheism of the Homeric Greeks entailed a conception of self deeply integrated in, and influenced by, the external world, one lacking private experience and individual intent. As such, individuals saw themselves as acting according to the will of the gods, not fully in control of their own behavior. Dreyfus & Kelly then proceed to describe the subsequent history of Western culture as the development of a "private" self, a history that culminates in the glorification of autonomy. This conception posed little problem to an understanding of meaningful action as long as there existed belief in a deity that provided external justification and criteria for action. However, in the absence of such a belief, reason for action vanished, leaving the now sole author of action – the individual – with the predicament of finding reasons to act.

To Dreyfus & Kelly, existential crisis brought about by perceived meaninglessness of action is not the byproduct of a god-less world. Rather, the problem can be attributed to the Cartesian and Kantian belief in an autonomous self. For the existential requirement that meaningful action demands external reason is wholly antithetical to the belief that human excellence requires action free from external influence. As Dreyfus and Kelly summarize the Kantian position, "Nothing outside of us – no God or other force, no impulse, no revered text, no parental demand, custom, or state decree – can be that upon which we base our actions when we are acting at our best" (p.141). Thus, if we are to satisfy the existential requirement, we must abandon the Kantian position and return to a Homeric notion of self where the cause of action is, in some significant sense, external to the actor. Stated differently, the possibility of a life perceived as meaningful demands that we value the call to action instead of the decision to act.

For Dreyfus & Kelly, understanding experience as a call to action is a matter of acknowledging and appreciating the triangulated relationship between experience, action, and care that fundamentally characterizes human interaction with the world. This relationship undergirds the notion of "shining" - the phenomenological quality of meaningful experience. According to Dreyfus & Kelly, experience in a particular domain has the potential to inspire care for that domain. Care, in turn, causes domain-specific engagement, which itself results in additional experience capable of reiterating the cycle. Such involvement is inherently meaningful, as the causal path from experience to care is not a matter of personal decision. Rather, it is the result of phenomenological experience, an experience that "happens" to you, independent of any conscious act or decision. This is the experience of shining. As a perceptual characteristic, shining describes a quality of experience that inspires care, as when a child brought to her first baseball game becomes an immediate and devoted fan of a perennially bad team. In this case, some aspect of the child's experience shines in a way that it does not for an individual for whom the game was "just a game." When and for whom things shine, though, is not prescribed – again, shining is not about consciously deciding to like something. Rather, it requires an openness to "being taken" by an experience, to forgo an explicit decision not to care. As Dreyfus & Kelly explain, "there are a wide variety of domains worth caring about and there are no objective, context-independent principles for determining which domains these are. You just have to try it out and see" (p.219).

Consider the implications of this last statement. When we try something out for the purpose of seeing, we engage in action in order to be affected in some way – to see if we like it, dislike it, find it boring, meaningful, interesting, distasteful, etc. We may act, but such action is followed by our response to the results of action. And if that response motivates us to engage, we simply cannot attribute ourselves as the source of our actions. Ipso facto, our actions are meaningful, as they are elicited by something other than us. Indeed, we may say that phenomenologically meaningful experience calls us to act in a manner similar to the call of a deity.

While the causal sequence from meaningful, shining experience to action seems somewhat intuitive, the reverse flow, from action to shining appears rather weak at first glance. For I can think of all sorts of actions that do not make my world shine – doing taxes, driving in traffic, booking a plane ticket online. Indeed, Dreyfus & Kelly imply the fragility of this link when they state that "whether a domain is worth caring about is determined by whether it appropriately elicits further and further meaningful involvement with it" (p.219). In other words, once active engagement in a domain – e.g. computer programming – ceases to lead to meaningful experiences we should look for other domains – perhaps playing the oboe – to care about. Certainly, this implies the possibility of a break in the cycle such that experience does not respond to action by shining. Thus, unlike the sequence from shining experience to action, the reverse relationship seems transient, contingent, and uncertain.

Yet, caring action does maintain some effect on our experience. To explain this effect, Dreyfus & Kelly invoke the concept of poiesis, the process of discovering phenomenologically meaningful distinctions in the world through the nurturing of skill. While we often view skill building as repetitive, mindless action, Dreyfus & Kelly offer a less caricatured description of the activity, one where "learning a skill is learning to see the world differently" (p.207). Thus, as the carpenter and surgeon hone their craft, they gain perceptual capabilities that enable them to discriminate progressively finer aspects of their domain. Such differences in perception elicit and direct subsequent action. The chess master is instantly capable of seeing the best move to take. The professional quarterback immediately sees the intent of the defense in its pre-snap formation and knows where to throw the ball. The mathematician sees the likely avenues to a solution. All these happen, as Wittgenstein (2001) says, "at a glance," without conscious deliberation. Instead, action becomes a product of perception, of how the world appears. In this way, skill building causes the world to illuminate the appropriate path of action – that is, poietic action causes the world to shine. Given that shining elicits and directs future action, such experience is, by definition, meaningful.

Shining in Education

The shining of a domain establishes a virtuous cycle where the triangulated relation among care, poietic action, and meaningful experience is, to some degree, self-perpetuating. Though it seems clear that the cycle is particularly vulnerable at the point where action elicits meaningful experience, poietic action that discloses the world in ever-finer detail often provides the reinforcement necessary to maintain iterations of the sequence – meaningful experience leads to care, care to action, and action to more meaningful experience. I would argue that as parents and educators, our views about educating children often imply belief in just such a cycle. When we bring our children to piano lessons and dance classes, our hope is that our children discover a domain that resonates with them. We hope that even the ambivalent efforts they put forth when first challenged to get a sound out of a clarinet, pirouette, or hold one's breath underwater, will lead to experiences that elicit care for that domain, experiences that they will perceive as intrinsically worthwhile. And we expect that once they have these experiences, they will be motivated to continue to actively engage that domain. On the other hand, if the time comes when experiences stop being perceived as meaningful, either at the start of engagement or years later, we usually realize that it is time for them to move on. As Dreyfus & Kelly state, "one must be prepared... to regret having been drawn into such a world and to allow oneself to be drawn to a more rich and meaningful one" (p. 219). So when a child is not motivated to catch a fly ball or play piano scales, we often look for, or encourage them to suggest, other activities that might elicit their engagement.

Of course, this is not always the case. There are parents who, for any number of reasons, do not relent in the face of statements such as "I hate piano," and "Swimming is boring." Perhaps they believe that their children simply need more time in the domain before they can experience it as meaningful. Or they feel that the skills and experiences are important even when perceived as meaningless. Certainly, the latter rings true when it comes to formal education where both parents and educators rarely speak of "moving on" in the absence of care or meaningful experience. This presents an issue with the Dreyfus & Kelly model, for it seems to imply that we have no choice but to endure meaningless experience when moving on is not an option. This is precisely the place where the NMAP task group ends up when they claim that the subject matter of abstract mathematics "may not be fully reconcilable with intrinsic motivation" (p. 4-17). And as I stated earlier, it is precisely the attitude that I refuse to accept. The question then becomes what to do in the absence of shining.

The answer to this question points to a weakness in the Dreyfus & Kelly model, for the model ignores the multitude and variety of types of engagement with a domain. It assumes that when I first started drum lessons at age nine, my experience reading quarter note patterns from a primer and playing them on a drum pad was *the* experience of drumming instead of simply *an* experience of drumming. It assumes that the experience of following the rules for solving first and second degree algebraic equations is what algebra is about. Certainly, in both cases, the activity is part of what constitutes domain-specific engagement. However, domains wear many faces, and while one face of a domain may not elicit shining, another face may. It so happened that I enjoyed playing simple drum music on a pad. Yet had I not, I may have been drawn in by being taught to play a rock beat on full drum set, or being allowed to bang willy-nilly to my heart's content. As Dreyfus & Kelly state, you just have to try it out and see. But what you are trying out is rarely a monolithic endeavor. Rather, it is comprised of numerous facets, a subset of which is presented in any particular interaction. This is particularly relevant when it comes to education, where a host of factors determines the domain face presented to students.

Trying it out also implies that domain-specific engagement is unmediated, a relation solely between the domain and the individual. However, I would argue that initial engagement with a domain is rarely unmediated, that the face of a domain is almost always presented by someone or something – teachers, parents, and peers as well as books, television, and other cultural elements. Thus, in the domain of mathematics, consider the general finding, reported by Roschelle et al. (2008), that despite spending comparable time in teacher training:

> American teachers typically focus on procedures, and their knowledge is generally rule-bound and fragmented. Chinese teachers demonstrate both algorithmic competence and conceptual understanding, and accordingly, their knowledge is typically more conceptual and interconnected. (p. 614)

If this is, indeed, the case, we can only wonder at the difference between the mathematics experiences of Chinese and American students. Similarly, Wilkins & Ma report that high school attitudes toward mathematics are directly affected by their teachers, noting that "if teachers choose activities that portray mathematics as static, boring, and unchallenging, students may view the subject as unimportant, and they may not perceive the usefulness of it" (2003, p. 61). Again, we are presented an example where presentation affects experience, perhaps to the point of determining whether a domain shines or not. In both cases, I am reminded of the six truths I mentioned earlier, and their relationship to meaningful experience in mathematics.

That we engage domains through mediated faces suggests an answer to the question of what to do when an individual is not allowed to move on from a domain that does not shine – simply present different faces. Of course, there will be some individuals for whom all possible faces fail to cause the domain to shine, but I find it surprising, to say that the least, that the NMAP task group could so readily suppose that all faces of abstract mathematics would *generally* fail to illuminate. Indeed, that seems to be the upshot of the task group statement. Roschelle et al. direct a similar criticism to the task group when they state that "there are many possible learning progressions into, through, and beyond algebra that can be equally mathematically rigorous....Some could offer students much more profound learning experiences, opening their eyes to the power and beauty of mathematics" (2008, p. 613).

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The effect of face is uniquely influential in the domain of school mathematics. To see why, consider the following interchange in a philosophy for children class involving ten eight-to-ten-year-olds on the subject of mindreading :

> Adrian: If you study math and science really hard for a long time, you can then put the two together to figure out a way to be better at it [i.e. mindreading].
> Shawn: I don't see how that can help you read minds any better. Well, maybe science, but not math.
> (At this point, there is mumbling and gesturing that indicates general agreement with Shawn's claim.)
> Me: Why do you say science, but not math?
> Shawn: Well, science can tell us about things, about what's going on inside our bodies. But math doesn't.
> Me: Doesn't what?
> Shawn: Tell us about our bodies.
> Adrian: But math is science. They're almost the same. When Einstein built a nuclear bomb, he used both math and science to make the explosion.
> Randy: I don't see the point. What does a nuclear bomb have to do with mind reading?

In this dialogue, Shawn expresses what seems to be the general position of the group: while science can tell you about complex aspects of the world – in this case, mindreading – mathematics cannot. Rather, mathematics sits in a void as a domain unto itself. While these are primary school children speaking, I suspect that such an attitude is even more widespread among high school students with regard to subjects in the college prep math sequence. Certainly, both the complexity and abstract nature of the material would suggest additional challenges to helping students relate topics such as natural logarithms and exponential arithmetic to the world. Wilkins and Ma's findings back this up, as they report a "substantial negative change in students' attitudes toward and beliefs about the social importance of mathematics throughout secondary school" (2003, p. 52). As Adrian's response illustrates, though, there are children that see mathematics as deeply embedded in the world. To these children, the perception of mathematics is different. Their engagement with the domain is infused with a *pre-reflective* understanding of its utility, its power, and often, its beauty. It is no wonder, then, that for children like Adrian the domain shines. This is not to say that such a face is required for mathematics to shine. Rather, math is simply *more likely to shine* when it is seen as embedded and relevant, as opposed to being situated by itself.

As mathematics educators seeking to foster intrinsic motivation to study abstract mathematics in an environment where leaving the domain is not a possibility, it would seem to be our obligation to present a face of mathematics that displays its connection to the world, particularly when dealing with abstract topics such as polynomial arithmetic and congruence. This presents a catch-22, though, as an important purpose of engaging these topics involves learning to think abstractly. Thus, attempts to reify the subject matter, to teach abstract mathematics using, for example, a project-based curriculum, could be seen as antithetical to the purpose of engaging abstract mathematics in the first place. Put simply, abstract mathematics needs to be taught abstractly or we are not teaching abstract thinking.

I have a particular sympathy for this line of thought. Indeed, students may learn about the Pythagorean Theorem through its application in a construction project. However, to the degree that we focus on the practical use of the theorem, we ignore what I see as a fundamental purpose of learning geometry – to gain an understanding of, and appreciation for, the nature of deductive systems, where assertions can be accepted only on the backs of previously derived propositions, accepted axioms, and definitions. Central to such a goal is intimate and extended work with proof analysis and construction, activities that are inherently abstract. The same can be said about learning algebra, where a major goal of teaching the subject concerns gaining conceptual fluidity with arithmetic abstraction. Approaching the subject matter by attending to its practical application, though, would require abandoning extensive engagement with the placeholder variables – the x's and y's – that constitute the essence of such abstraction. No doubt, much of the practical application of algebra is more than one degree separated from learning the material, as basic algebraic skills are generally useful as tools for solving problems encountered in higher level mathematics, engineering, and science. Thus, for the large majority of students who expect to have no need for such skills, questions about personal utility are legitimate. For these students, mathematics pedagogy must help them perceive the present value of engaging the domain.

This is precisely where engagement with philosophical discussions can play an important role. Unlike efforts to embed high school mathematics in a practical milieu, philosophical engagement with the nature of mathematics offers the possibility of connecting mathematics to the world without potentially compromising the abstract nature of its study. It displays a face of mathematics that strict engagement with abstract topics fails to present. Epistemological and ontological questions such as "Is mathematics an invention or discovery?" allow students to address the relation of mathematics to material reality – whether math is a model that we use to understand the world or if it is somehow embedded in it. Other questions suggest additional types of connections. We might ask if mathematics factors into our conception of what it means to be a person, or if it has the power to change our conception of self. These questions touch on issues of technology, cognition, and consciousness, which in my experience, elicit great interest among teens. We can also extend discussions to ethics by asking if we can or should use mathematics to help guide our ethical decisions. Even the aesthetics of mathematics is a viable topic, as we might discuss the relevance of beauty to the domain – if, for example, one solution of a first order equation or geometric proof is more beautiful than any other. In each of these cases, we provide students the opportunity to explore the concerns of mathematics, and how those concerns relate to lived experience.

Take, for example, a snippet of an interchange about the ontology of geometry in a group of 9th through 12th grade students . In this case, the question that I initially posed was "Is mathematics a discovery or an invention?"

> Quinn: It's just a model, a model of the world.
> Amari: Yes, the model is made from definitions, and we see how much we can say about them. But that doesn't mean the definitions exist. They're just definitions which we made up.
> Me: So when we define a circle as the set of all points equidistant from a point, that's just a definition. That's what you're saying?
> Quinn: Yes. Points don't exist – everything in the world has three dimensions and points don't have any.
> Alexis The definition is for a perfect circle, but things don't have to be a perfect circle to be a circle. Circles are circular. And the model works with those.
> Quinn: Just because the model works doesn't mean we didn't create it. And it works only approximately.
> Alexis: But it works.
> Quinn: I mean, circumference is πD. But if you measure something like a Frisbee it's not exactly πD. It can never be exact.
> Alexis: But nothing is ever exact. And for something to work, it doesn't have to be exact.
> Amari: But that doesn't mean it exists outside of us.

This interchange formed but a small part of a multi-session discussion that touched upon several philosophically-based mathematical issues including the nature of infinity and time. Yet, I would think it evident even from this brief extract that these students were offered something that very few high school students experience. They were provided the opportunity to construct big-picture, comprehensive answers to the meta-questions of the domain – what we do when we do mathematics, why we do it, and how possible answers to these questions relate to both the first-order questions of mathematics learning and, more generally, contemporary life. This is a wholly different experience than hearing from adults about the utility of mathematics. Rather than gain discreet information about its relevance to their future adult lives, students construct with their peers knowledge about what mathematics is – here and now – a knowledge that I suggest is more likely capable of transforming their perception of mathematics than any declarations of utility. In this way, we may say that philosophical engagement with mathematics has the potential to get students to *feel* the value of abstraction. Indeed, I believe that the dialogue above had precisely this effect.

To further appreciate the possibilities of participating in such discussion, consider the current perception of mathematics as disclosed by the six truths. In a worst case, mathematics is seen as getting answers by following rules. Those answers sit in a void, and most students perceive the rules as facts requiring memorization instead of conclusions to logical arguments. In best case scenarios, I suspect that students learn from teachers, parents, and textbooks examples of how particular aspects of mathematics – natural logarithms, for example – are used by mathematicians, researchers, and weather forecasters. These students can probably spit back facts about the relevance and utility of mathematics. Still, I take it that knowing this information does little more to make mathematics personally important than telling students that they need math skills for their future studies or careers.

Ultimately, it seems clear to me that helping students develop a more positive attitude towards mathematics requires more than simply imparting some rational understanding of its utility and connection to the world. Rather, the goal should be a transformation of perception, where individuals pre-reflectively "see" the connection. And transformation of perception is the essence of Dreyfus & Kelly's notion of shining. The shining face of a domain inspires care, and in doing so, beckons for domain-specific engagement. No doubt, the abstract nature of the college prep math sequence presents challenges to making the domain shine. As such, I have suggested that teachers need to explore the presentations of other faces of abstract mathematics, faces that can make the domain shine for the significant number of students who would turn their back on it if they could. Philosophical engagement with mathematics presents just such a face.

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