Conceptual Spaces at Work 2016

Conceptual spaces as a framework for pedagogy in the sciences

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‘But though *In a Silent Way* wasn’t exactly jazz, it certainly wasn’t rock. It was the sound of Miles Davis and Teo Macero feeling their way down an unlit hall at three in the morning’.

– Philip Freeman

A connection between pedagogical and epistemic problems

- What is behind the scenes in my talk: an explanation for theory-preference that relies on diachronic justifications for *epistemic virtues*. (I'll explain what those are shortly.)
- These virtues more or less track *pedagogical virtues*: the grounds for how we should communicate new concepts to one another.

- This is a possible similarity between what grounds good pedagogy and what grounds good epistemic behaviour in general:
    - Teachers deal with known starting and endpoints, and the pedagogical virtues set constraints within *previously explored* concept-space.
    - Philosophers of science deal with an unknown endpoint and attempt to develop rules or norms to constrain possible set of *future moves* in concept-space.

- Rules on inquiry set regulate the movement between *conceptual spaces* to and the overall *efficiency of the path*.
    - These rules apply to both
        - reconstructing previous inquiry in the classroom
        - directing future inquiry.
- This, coincidentally, can be modelled using Gärdenfors' work (2000) and directional graphs, representing the past development of a scientific research programme.

- In contrast to Zenker and Gärdenfors (2014), these grounds are *realist* rather than instrumentalist:
  - there is a correspondence relation between scientific theories and the world and between conceptual spaces and the world (unknown and possibly unknowable)
  - scientific theories and conceptual spaces may be more or less empirically adequate (knowable)

- The focus on pedagogy sidesteps the well-known difficulties of determining correspondence between theory and world
  - our interest here is merely the correspondence between conceptual space and scientific theory, not whether the theory is true or false.
  - our other major interest is whether the theory or conceptual space is presently empirically adequate

The pedagogical problem and Gärdenfors

- Consider this question: How should teachers better introduce new concepts to students?
- Consider a related question: How should students better learn new concepts from teachers?
- Consider one more: Is the classroom an idealisation of (guided) inquiry?

- The answer is obvious: professors should just teach students current physics. (Yes, people have *seriously* advocated this to me and others.)
- This position is likely the worst possible approach to teaching.
- By introducing a new domain or a drastic revision to the boundaries of an old concept, these new concepts are, from the student's view, *mere* labels: there is no corresponding conceptual space to make sense of the talk about theory.
- The student may be unable to follow what is occurring in the classroom and subsequently emotionally shut down.

Epistemic vs. pedagogical virtues

- Let's go deeper: why is this approach *so* absurd, but seriously advocated by people that have never taught before?
- Consider the following distinction between synchronic and diachronic perspectives:
    - A synchronic theory describes relations of support and coherence between a system (of beliefs, theories, concepts) at a single time
    - A diachronic theory describes changes (to beliefs, theories) over time
- It's reasonable to have both kinds of theory at our disposal, but we want a helpful balance of the two and not neglect one at the expense of the other.

- Too much emphasis was on the synchronic pedagogical virtues: these ‘armchair’ attempts to teach start at the *end product of previous inquiry*: we guide inquiry by attempting to maximise true beliefs, maintain coherence, and minimise false beliefs by laying out what our currently best models are.
- Many of the explanations for why we value particular epistemic virtues and disvalue epistemic vices rely on the synchronic side at the expense of the diachronic side.

- If inquiry were synchronic-oriented, we would want to maximise true beliefs. We'd also want to limit exposure to false beliefs.
  - Namely there would be little talk of our past mistakes.
- Lastly, we want to retain coherence.
  - But much of history of science is about the discovery of incoherence between our expectations and the world.

- Out of all possible conceptual spaces, we want to pick the one that satisfies all these criteria and start teaching it immediately.
- Similarly, out of all possible theories, we want to pick the one that satisfies all these criteria and terminate further inquiry.

Some obvious downsides

- Learning in the classroom becomes rote copying of the teacher. Recall Feynman's report of teaching as rote memorisation and repetition in Brazil: a case of ‘cargo cult’ teaching.
- If the students cannot follow these concepts, they are labelled ‘not smart enough’.
- Priorities askew, leading to ‘teaching to the test’: the student remains active and capable repeaters, but are not *learning*.

It doesn't reflect how we teach

- Our very models are known to be false: they are often abstractions that provide conceptual ease to their use.
- We work with these historical fictions because they ease students from one conceptual space to another.
- Much of the learning experience is coming to grips with the failure of coherence between expectation and reality, internal coherence within a set of beliefs, etc.

- I don’t want to say synchronic-oriented approaches are wrong or misguided
    - I argue only that they can be over-emphasised.
- None of these epistemic virtues apply to learning *per se,* but selecting the best end state to inquiry.
- These synchronic-oriented approaches look less plausible if we think of learning in the classroom as *guided inquiry.*

- What have we learned by examining an obviously absurd scenario?
  - Teachers cannot intelligibly communicate to students using concepts that differ *too* much from their present conceptual scheme.
  - In order to arrive at that end state, we cannot do so in one step, but through intermediary steps.
- *How many steps do we need?*

A more plausible start

- Like storytelling, many attempts at communication are *narrative-driven*:
  - We begin with where we *were*, explain how we arrived *here*, and end with where we are now *going*.
- E.g. ‘This was the problem, here was my solution, these are the new problems’, etc.
- This provides context, a *Weltanschauung*, a dialectic, etc.

- An analogy: although many routes lead to Rome, the best route for us to take at any one time may be unique.
- What is the most appropriate route for students to take from their starting point? How should teachers help guide students on their journey?

- That answer requires examining their usual starting point, since the supposed ‘best’ route may not begin at where the students currently are.
- We want the route that is best *for the student*.
- Where do students start?

The genetic *a priori*

- Students have a number of Piagetian ‘genetic’ or psychological *a priori* modes of thought, dispositions, expectations, taxonomy or anticipations (Piaget, 1950).
- This approach to understanding our ‘default’ conceptual spaces is an evolutionary interpretation of Kant’s categories.
- Specifically, in physics, these conceptual spaces often correspond to what is known as ‘folk physics’.
- This approach is reliable in almost all everyday circumstances.

'The faculties by which we arrive at a world view have been selected so as to be, at least, efficient in dealing with other existents. They may, in Kantian terms, not give us direct contact with the thing-in-itself, but they have been moulded by things-in-themselves so as to be competent in coping with them'. (Waddington, 1954)

- The bad news: the genetic *a priori* does not save the evidence. It is often mistaken.
- For our purposes, focus on the difference between the average first-year student and a theoretical physicist.
- We desire that, after their journey, the student has the conceptual spaces approximating those of a modern physicist.

- One answer is fairly simple:
  - we tell students where we started from (*folk physics*),
  - how we got here (*the entirety of the history of physics*),
  - and where we are now (*current physics*).
- This approach is the guided reënactment of the history of physics.
- Teaching is the imaginative reconstruction of the reasoning and experimental processes that lead to concept revision.

- Obvious downside: as *uneconomical* as possible:
  - If we were to develop a fairly accurate model of the history of physics, it would be a dense directional graph that would take decades to understand.
- Another downside: *incomprehensible*.
  - We cannot hold these minor distinctions between theories in our heads.
- This is clearly too roundabout and unwieldy.

- This attempt at graphing each stage would still be an *idealisation*: you'd have to model the changes to conceptual spaces of each contributing scientist.
- If we are to idealise away the particulars and look for *trends*, this is the way of viewing learning as rational reconstruction of the development of a problem-situation (Lakatos), rather than *total* reconstruction.
- This idealisation is *as* reasonable for our purposes as the taxonomy of evolutionary biology: it focuses on salient differences.

Finding the 'golden mean'

- Teachers want to minimise the amount of conceptual stages between where the students begin their learning and the point at which the students can understand theoretical physics.
- We've changed the problem: From 'How should students better learn new concepts from teachers?' to 'What are the fewest number of *manageable stages* of conceptual spaces between models of "folk physics" and current theoretical physics?'

- We want to engage in concept-revision *when it is most appropriate*. Namely, we desire *economy*: we want those smallest number of necessary steps.
- How do we introduce the minimal necessary number of conceptual revisions and not trigger apathy or confusion when transitioning between conceptual spaces?

Restating the problem

- The pedagogical problem is more appropriately stated (now for a third time) as a balancing act between maximising long-run and short-term aims.
  - Long run: what is the shortest path in a strongly connected directional graph G?
  - Short term: between any series of neighbouring nodes in G, which node preserves the structure of the vector space of the previous node?

- Metaphorically, we want…
    - The most economical path to Rome *that is also* the ‘safest’ path to Rome, where safety is a measure of closeness between each city on the path.
- From Gärdenfors (2000), *we can model the similarities between nodes by distance*.
- Since these nodes represent conceptual spaces, we can measure the similarity of conceptual spaces in possibility space.

Solving the problem

- Gärdenfors' conceptual spaces provides a short-term model of concept-acquisition and revision *inside* each node.
- It can also be integrated into this long-term model in dictating *movement* between nodes.

- We (finally!) have the following question:
  - What is the shortest *distance* in a strongly connected directional graph?
- The answer to this question will maximise our short-term and long-term aims:
  - It is the most economical *and* 'safest' path from our starting node to end node.

- This approach emphasises important diachronic constraints to movement between nodes. We have a far more richer and specific *theory of movement*.
- For pedagogy, we have a way to model which key points should be covered in moving from pre-theoretical beliefs to a well-informed student:
    - The path corresponds to the key research programmes that *should* be taught to students, if our aim is to maximise both economy and 'safety' of their educational 'journey'.

- We have very weak synchronic constraint on theories:
  - the predictions of theory do not contradict accepted empirical evidence at time *t* (Popper, 1959) (*NB*: the single realist constraint) *and*
  - the theory is *close to* the minimum message length when expressed in some language *L* (Wallace and Boulton, 1968) *and*
  - the theory survives rigorous thought-experiments for consistency (Brown, 1991)

This solution applies elsewhere

- This diachronic approach helps gives reasons for accepting these weak synchronic constraints
  - how we should reconstruct our previous path
  - how we should proceed from here
- I'll cover two examples of the benefits of diachronic theory: the problem of simplicity and the rule of preservation.

The problem of simplicity

- Rhetorical question: why should we think that the simpler theory is more likely to be true? Answer: we shouldn't. Simplicity does not give a reason to believe a theory is true.
- From a diachronic view, simplicity takes on an valuable epistemic and pedagogical role:
  - Simplicity is part of a good *rule of motion*: start simple, follow the available evidence, and engage in minor concept-revision.
  - If the theory is in danger of becoming too complex, shift to a nearby simpler theory that equally fits the available evidence.

- For example, Kevin Kelly (2004) argues on the basis of formal models, a simplicity preference is part of a procedure that reliably approaches the truth given the available evidence *via* the fewest dramatic changes of the conceptual space *en route*.
- This gives a good rule of motion for teachers: start simple, introduce new information, and when the theory becomes too *cognitively unwieldy*, shift to another simple theory that accounts for the evidence.

The rule of preservation

- It's reasonable to not alter or discard theories unless there is a reason to do so. If our goal is to believe theories that are true, then it is hard to see why it should be a good thing.
- For any body of evidence it is possible to construct a theory that (more or less) fits the available evidence (problem of underdetermination).
- Other theories equally fit the available body of evidence. Why should we privilege *our* theory over another? Because it is ours? Why not switch from one theory to another or remain indifferent?

- The answers are trivial under this approach:
  - It would result in the disruption in the development of key theoretical concepts.
  - Even if it were possible in practice, constant switching would do nothing but produce undue cognitive demands.
- The practical and epistemic considerations are therefore in line with one another: we would need a good reason to give up on our conceptual spaces.

- The corollary of the problem of underdetermination is that for any point in time two or more theories may fit the available evidence, but that at some time in the future they may *not*.
- This explains the admittance of theory-change and concept-revision, since the classic problem of underdetermination, coupled with the rule of preservation, would prohibit updating from one to another...

- … *unless* one has a prior understanding of both schemas, as well as their relative benefits. This produces the opportunity of comparing the two, for example:
    - one theory fits the available evidence better than its rivals (Eddington’s 1919 experiment)
    - both theories each save the phenomena, but one satisfies a number of theoretical virtues better than its rivals (cf. Quine)

A brief case-study: teaching Galileo

- Galileo argues in the *Discorsi* that the speed of all bodies fall at the same rate, a thought-experiment showing the absurdity of Aristotelian physics (James R. Brown)
- If, according to Aristotle, heavier objects fall faster than light ones (H>L), what if a cannon ball is attached to a musket ball and released from a great hight?
- We get an absurd conclusion: the light ball will produce drag on the heavy ball, so the speed will be slower than the heavier ball alone (H > H+L)
- But the combined system is heavier than the heavy ball alone, so it will fall faster (H+L > H)

Downsides, given this model

- One of the biggest tradeoffs is the amount of time dedicated to teaching this way. *Rote memorisation*—i.e. the shortest route—*is more economical*.
- This form of teaching requires perpetuating myths and misleading reconstructions about history of science.
- Science may be misinterpreted as Whiggish.

Recap

- We began with the questions: ‘How should teachers better introduce new concepts to students? How should students better learn new concepts from teachers?’
- We moved to: ‘What are the fewest number of conceptual spaces between models of “folk physics” and current theoretical physics that is above naught?’
- We concluded with the question: ‘What is the shortest distance in a strongly connected directional graph?’

Final thoughts

- We can say that the current pedagogical system is embedded in a *good process*: it has a successful track record in guiding inquiry.
- But this is an empirical claim, and itself a test of this model of learning:
- we could attempt to accurately model the history of science and see what is the *actual* shortest distance.
    - if it should differ from what we currently teach, we can implement it in the classroom setting.

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