Knowledge Analysis: An Introduction

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Knowledge Analysis

A technique for generating and analyzing data to elucidate the content, form, and dynamics of knowledge for the purpose of understanding learning

- Knowledge is one of the most important concepts in education
- However, knowledge quickly becomes a subtle business What is "knowledge" anyways? What ways of describing it are productive for understanding how individuals learn?"

Intellectual Roots

- Piaget's genetic epistemology and related educational approaches such as constructivism
- Cognitive modeling and information processing
  - Aim towards explicit, computer-runnable models of what knowledge people have and also how that knowledge works and develops

History

- Cognitive revolution (~1970's and 80's) in education research provided some tools for studying knowledge
  - Knowledge thought of in terms of mental representations and processes of individuals
- Breakthrough findings
  - Students come into school with a rich experience of the physical world and draw upon it in their formal schooling
- Does it make sense to call these intuitive "understandings" about the physical world gained through experience "knowledge"? (Yes…)

Motivating phenomenon: Contextual dynamics of student explanations

J, a university physics student, is asked to describe the motion of a ball tossed vertically in the air. The following is her first description of this phenomenon.

J: Not including your hand, like if you just let it go up and come down, *the only force on that is gravity.* And so it starts off with the most speed when it leaves your hand, and the higher it goes, it slows to a point where it stops. And then comes back down. And so, but *the whole time, the only force on that is the force of gravity*, except the force of your hand when you catch it. And, um, it … when it starts off it has its highest speed, which is all kinetic energy, and when it stops, it has all potential energy – no kinetic energy. And then it comes back down, and it speeds up again.

(diSessa, 1996, p. 720; emphasis added).

Shifting attention leads to explanation re-configuration

Then she is asked what happens at the peak of the toss.

J: Um, well, air resistance, when you throw the ball up, the air…It's not against air because air is going every way, but the air force gets stronger and stronger to the point where it stops. *The gravity pulling down and the force pulling up are equal*, so it's like in equilibrium for a second, so it's not going anywhere. And then gravity pulls it back down. *But when you throw it, you're giving it a force upward, but the force can only last so long* against air and against gravity – actually probably more against gravity than against air. But *so you give this initial force*, and it's going up just fine, slower and slower because gravity it pulling on it and pulling on it. And it gets to the point to the top, and then it's not getting any more energy to go up. You're not giving any more forces, so the only force it has on it is gravity and it comes right back down

(diSessa, p. 720, emphasis added).

Discussion of J

- Before the follow-up question about the peak of the toss, J appeared to be a competent physics student giving a normative account of this phenomenon. Her subsequent account invokes a common misconception.
- The interviewer's intervention (asking J to consider the top of the toss) was designed to probe for the stability of her apparently normative model of a toss by subtly highlighting different aspects of the situation. In response to this shift in attention, she reconfigured her explanation.
- diSessa's analysis of J illustrates one of the central phenomena uncovered by conceptual change researchers working in the KA tradition: students can produce both normative and non-normative explanations in response to what is ostensibly the same line of questioning, in response to subtle shifts in attention to different aspects of the phenomenon.

Phenomenological Primitive (p-prims) as a new form of knowledge (diSessa, 1993)

- P-prims are very simple schemas that are developed through experience in the physical world
- They are nonverbally encoded.
- The function of p-prims is sense-making
  - When activated, p-prims are recognized and evoked as a whole
  - They account for people's comfort with certain situations or surprise in others.

A prototypical example: Ohm's p-prim

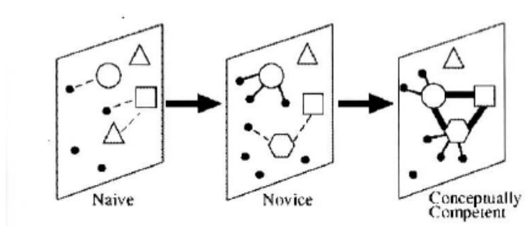
Three parameters: effort, resistance, result

Effort controls result, moderated by resistance [more effort, more result; more resistance, less result; …]

Examples:

- Push harder, things go farther/faster; Bigger weight (more resistance) results in less result

Systems Perspective and Conceptual Ecology



- Systems perspective on change and development
- We think in terms of a conceptual ecology involving many types of knowledge elements and knowledge subsystems
- Over time, new elements arise, even new types of elements. Some older elements may fall out of use or remain but be used only in everyday as opposed to technoscientific purposes. Connections change as the knowledge system is reconfigured to achieve expertise.
- Conceptual change research from a Knowledge in Pieces perspective is interested in is how later states emerge gradually out of prior ones. This mode of research is microgenetic learning analysis (Parnafes & diSessa, 2013)

Principles of KA

1. **Knowledge is constituted in mental representations.**
2. **Knowledge can be non-propositional and encoded in various modes** (e.g., visually or kinesthetically encoded). This view distinguishes knowledge* from more traditional views of knowledge.
3. Studying mental representations of individuals requires highly **nuanced accounts of content**.
4. **Intuitive knowledge is an important target of study** and forms of naïve knowledge are diverse, rich and generative.
5. **Moment by moment accountability** to data of learning
6. **Intellectual performance is highly contextual.**

Counter Principles of KA

1. **Rejection of the "subset" model**
2. **Skepticism of Common-sense knowledge terms**
3. **Skepticism towards a priori modelling languages**

Framework for Comparing Methodologies (Martin & Sherin, 2013)

- **Empirical set-up:** What instances of thinking and learning are studied? (e.g., interviews, classroom discussions, everyday conversation)
- **Capture:** What aspects of the learning phenomenon are captured and how are they captured (e.g., video of interaction, field notes)
- **Reduction:** What do we attend to in what is captured? (e.g., right/wrong answer or do we pay attention to all of what students say or do; do we reduce the data to a set of codes)
- **Pattern finding:** How do we find patterns in the data? Do we look for statistically significant correlations in codes? Do we read transcripts to draw impressions that may be generalized?
- **Reporting:** How do we report our results to other researchers?

Knowledge Analysis:

Empirical Set-up

Goals:

- Understand Content, form and dynamics of individual knowledge and how it develops.
- Uncover subjects' "natural" ways of reasoning about phenomena, not to assess their state of understanding with respect to a normative standard.
- A characteristic concern for KA is documenting contextuality in knowledge use.

Assumptions:

- What individuals say or do is a window into their thought processes
- We as analysts can make a model of these thought processes by observing verbal/video data of people reasoning

Conditions:

- Can be investigated both in researcher-manufactured context (clinical interviews) or naturally occurring contexts (students working together in small groups on a task)
- Key design principle no matter the context is to offer multiple possibilities to observe contextuality
  - Offering multiple representations of the "same" issue
  - Multiple opportunities to consider the same event or idea
  - The researcher may deliberatively prompt other ways of thinking to measure the subject's receptivity

Knowledge Analysis:

Capture

- It is critical for researchers to put themselves in the position to notice what subjects are focusing their attention on and what is salient to them
- Data
  - Video and audio records
  - Representations and artifacts the subject creates/interacts with are considered in the analysis
- Desiderata
  - Position camera(s) so that indications such as the subjects' eye gaze, gestures and the way they interact with artifacts and materials are available for later study

Knowledge Analysis:

Reduction (Transcription)

- Video recordings are transcribed.
- Transcripts are iteratively improved to include features of the interaction or context that are thought to be relevant to the question at hand (e.g., gestures, eye gaze, and lengths of turns and pauses).
- Work that follows is typically done using these transcriptions, but also directly consulting video, especially for situations where eye gaze and gradual construction of a visual representation are involved

Knowledge Analysis:

Reduction (Attentional Foci)

- **Flow of individuals' actions or reactions** can be indications of what they find salient
- **Evidence that a subject takes a statement to be explanatory** and an adequate basis for reasoning is important information (e.g., Does the subject react with an implied "of course" or contrarily, with surprise?)
- **Commitment and confidence** are important features that can be implicated in pacing, prosody, and tone of speech.
- **Time profile** (e.g., What ideas about a topic were expressed first? Do some ideas appear to be generated on the spot or do they appear to be reasoning on the basis of ideas that were pre-compiled)

Knowledge Analysis:

Reduction (Schematization)

- **Heuristic:** Attempt to recognize patterns and define knowledge organization based on schematization of knowledge-in-use in a context (endogenous) as opposed to imposing a pre-defined organization (exogenous).
  - "Follow the subject's eye" (What are they attending to?)
  - "Follow the subject's mind" (What are they inferring?)

Knowledge Analysis:

Pattern Finding

- A common type of reduction takes the form of the selection of episodes that illustrate a phenomenon at issue and the creation of theory-based narrative accounts of these episodes.
- The data is examined in an open way with respect to the topic of interest, episodes illustrating a particular issue are selected, a working theory is built, and then reduced accounts of episodes employing the theory, as it currently exists, are produced. The fit of the theory to the episodes is then evaluated and the process iterates.
- The iterative data-grounded approach to developing theoretical accounts shares features with grounded theory and the constant comparative method (Glaser & Strauss, 1967) as elaborated in Parnafes & diSessa, 2013.

Knowledge Analysis:

Reporting

- In many non-KA qualitative analyses, the rigor in the analysis comes from
  - Having a large number of subjects to guard against anomalous findings with small samples
  - Coding and measuring agreement between multiple coders in order to demonstrate the operationalization and well-definition of coding schemes.
- In the prototypical case, KA research articles present the theoretical frameworks that have been developed (during pattern finding) and they illustrate and establish the plausibility of the framework by drawing on selected theory-based narrative episodes.
- Kapon & diSessa (2012) discuss theoretically-motivated validation principles.

Methodological Case Study

(Understanding "Fastness")

Parnafes, 2007

- The general aim was to try to understand the ways that students' reasoning with simulations of simple harmonic motion could help build their understanding
- The activities in the study revolved around:
    - A purposefully rich and varied set of physical means for exploring the phenomenon (spring rods, physical pendulums, springs, etc.)
    - A dynamic and interactive simulation of harmonic motion, itself with several coordinated view that highlighted various aspects of harmonic motion

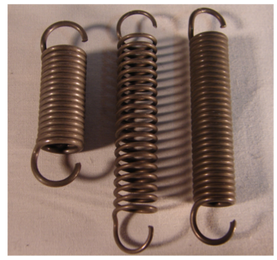
Understanding "fastness"

Empirical Set-up

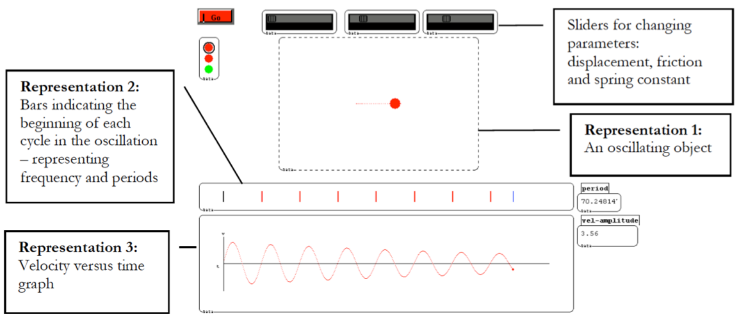
- Parnafes had data from 8 pairs of high school students in which students reasoned about simple harmonic motion (oscillation) using both computational representations and physical oscillators.
- Over the course of an open-ended session (~90 minutes) students were asked to discuss similarities and differences between various oscillators.
- The researcher intervened only occasionally to ask pairs to consider certain aspects of the situation and to prompt them to continue if they came to local impasses
- The design of the activity gave students agency to explore a relatively complex topic in a relatively unstructured way without specific expectations for the endpoint of their investigation.

PHYSICAL OSCILLATORS

Springy rods, pendulums, springs



DESIGNED COMPUTER SIMULATION



Understanding "fastness"

Capture

- The students' work was videotaped with one camera, positioned so as to capture students' faces and upper bodies as they talked with each other and played with the oscillators, and also to capture screen and mouse movement.

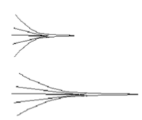
Understanding "fastness"

Reduction

- Parnafes reported that she started with a preliminary and open analysis of the data to identify segments of particular interest for understanding the processes by which interaction with the representations seemed to support development of students' understanding.
- Such moments and issues were characterized and names and schematizing their properties began.
- This preliminary stage was followed by a search across all the data for similar occurrences.
- An issue that became core to her study was that students seemed to use the term "fast" in different ways, without noticing.

SPRINGY ROD CONTEXT
(Fastness as vibrations per unit time)

Rachel: If you hold it, like, if you hold it from here (*holds the springy rod so that only a short part oscillates, and pulls it; the sound of the vibrations is heard with a high frequency*), like, from close, then it's, it moves faster. And when you hold it up here (*extends a longer part of the springy rod, and pulls the end. the sound of the vibrations is heard with a lower frequency*) it goes slower...



PENDULUM CONTEXT
(Fastness of as distance over time)

Rachel: (*Pushes the ball again*) You see? It's faster… and then, when you hold it here (*shorten the string and holds the string doser to the ball*), when you hold it close, then it (*the shorter pendulum*) seems a little slower, I don't know, it seems a little slower… and if you hold it at the top…

OP: Can you show me how it seems slower? If you hold it like that... (*referring to holding the string doser to the ball)* Why do you say it's slower?

Rachel: And it has less space to move, and this one is like more space to move.

Understanding "fastness"

Pattern Finding

- Not only did students appear to have multiple undistinguished ways of thinking about "fastness" it appeared that the computational simulation helped them to begin to sort some of this out.
  - How did this change happen? Why did it happen only when these students used the representations?
- The next phase involved negotiating between candidate theories and data.
  - Coordination class theory (diSessa & Sherin, 1998) exemplified the perceptual processes relevant in studying the interplay between external representations and learning, it was selected as a starter theory for the analysis.

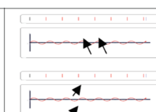
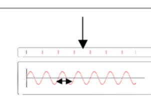
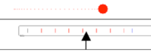
Exploring harmonic motion with the simulation

"Fast" meant "more X per unit of time" in all aspects: more bars on the timeline of the bar representation and higher peaks on the timeline of the graph representations.

First the students in this interaction (Sue and Robin) hypothesized that the slower the oscillator goes, the lower the graph is, and the further apart the bars are. Their experiment corroborated this: "OK, that's much slower and these things are much further apart. And the sine wave is squished."

The context that they explored at first did not have a strong potential to problematize or challenge their use of the term "fast," as changing the spring constant led to changes in both frequency (or period) and velocity.

In the episode present to the right, they controlled the displacement, a parameter that affects the linear velocity of the oscillation only, not the frequency (or period), and this problematized their use of the term "fast" in its broad meaning.

Part 1		
1. Robin:	So (1), these are at the same skinniness level but they are not as high…	
2. Robin:	Like, remember when it was fast these things were really high...	
3. Sue:	[yeah] [yes]	
4. Sue:	[And it touches the axis at the same points]	
5. Robin:	But these are the same (1.5); I think these are the same... I think...	
6. Sue:	Are they?	
Part 2		
7. Robin:	Yeah, let's see	
	(Robin changes the displacement back again to the right end and re-runs the representations)	
8. Robin:	No, these look closer together.	
9. Sue:	No, [no ... it just started out…]	
10. Robin	[No, these look like the same] Those are the same but these are higher.	
Part 3		
11. Sue:	So, like, it's moving faster, it's…(2)	
12. Robin:	But the periods are the same, that's… [the periods]	
13. Sue:	but, in	
14. Robin:	[but it's going farther]	
15. Sue:	it's going farther in the same [amount of time]	
16. Robin:	[So there's more motion] in the [same amount of time.]	

Understanding "fastness"

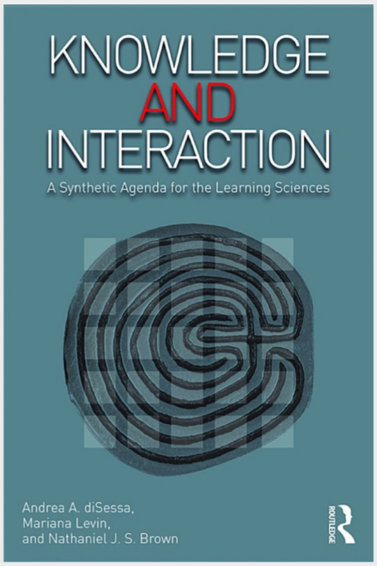
Pattern Finding

- The affordances of the representations played a major role in the process of distinguishing meanings for fastness.
  - The students now had clear and stable perceptual foci that allowed them to detect the patterns in the simulation: the "skinniness" of the graph (or the distance between the bars) and its height.
  - After detecting these two representational patterns—the distances were the same, but the peaks of the graph were higher—the students looked for their meanings in the physical world.
  - This meaning was established by mapping the varying representational features to the correspondent aspects in the physical world. T
  - he oscillating object representation, with its resemblance to the "real thing," served as a bridge between the other representations and the physical world.

Understanding "fastness"

Reporting Results

- Parnafes' main result was a set of four interrelated mechanisms that illustrated how the computational representation supported students in refining their understanding of "fastness"
- Episodes that illustrated each of the mechanisms were selected for inclusion in the journal article (Journal of Learning Sciences)
- Parnafes' study showed how one could extend coordination class theory to illuminate the process of learning with computational representations



- The episode of Sue and Robin was reanalyzed in Danish, Enyedy & Parnafes (2016) as part of the KAIA project (diSessa, Levin, & Brown, 2016).
- The prior KA analysis using coordination class theory concerned "How do we readout specific information we need from our immediate context in order to better understand the world at large?" Analysis with pair as a unit.
- New goal of KAIA project analysis: By looking at students' interactions in a learning environment, it became possible to see how students' coordination classes change over time and how they established intersubjectivity in their understanding. Analysis of girls separately.

Creating a KAIA integrated analysis

Step 1: Review the video data with a goal of exploring how the system (the two students and the computer simulation) engaged in the task at hand.

Step 2: Parse the interaction into subparts, delimited by key visible transitions in students' knowledge, the nature of their interaction, or both.

Step 3: Conduct a separate pass at KA and IA (done by one team member especially familiar with each of the methods)

Step 4: Integrate analyses (done by third team member with knowledge of both methods)

Findings of the Integrated Analysis

- When they began the project of developing an integrated analysis, the researchers of this team noted that in conducting the KAIA analysis of this data, each approach was incorporating in an intuitive way techniques or foci from the other:
  - The KA was also concerned with intersubjectivity, specifically through considering what "aligned" actually meant (i.e. What is it that the two girls establish intersubjectivity around?)
  - The IA tracked a conceptual line, puzzles, potential disagreements, etc. so it inherently tracked knowledge, albeit not at the level of detail of a coordination class analysis.
- The integrated analysis helped to illustrate the ongoing relationship between the social moves, which are used to build intersubjectivity, and the conceptual underpinnings of that intersubjectivity.

Thank you!

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