The *Pivot*: Identifying Emergent Tactics in Distributed Epistemic Games

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Abstract: The theoretical machinery of epistemic forms and games has been used to describe the knowledge-building processes of individuals. Humanity is faced with challenging problems in an increasingly complex world, and it is clear that productive knowledge building across domains depends on collaboration. To better characterize this collaborative knowledge building, we present a framework we call *distributed epistemic games*, in which the knowledge-building activities are carried out by a group distributed across time, space, and expertise. These distributed games are supported by tools such as computing technology and the internet, which allow individuals to connect, communicate, and coordinate their work. We introduce the construct of a *tactic*: a collection of moves found in distributed epistemic games, which together serve a larger purpose. Finally, we describe a specific *emergent tactic*, which we call the *pivot*.

Introduction

As our world grows increasingly complex, our society is faced with increasingly complex problems. Addressing these problems can be challenging; indeed, some seem impossible to solve. Isaac Asimov once described a thought experiment in which the challenge wasn't the problem itself, but instead, that "only so many people could gather round the knowledge," so the problem remained unsolved (Asimov, 1989, p. 62). This limitation is not absolute, as there is a possibility of gathering more minds and therefore finding a solution. Constraints of time, space, language, logistics, interest, and expertise must be handled in order for more minds to work on the problem together. The thought experiment implies an opportunity to solve difficult problems by getting enough people gathered around them.

Decades earlier, Vygotsky (1981) coined the phrase *zone of proximal development (ZPD)* to describe those tasks which were only possible if a learner received help from someone with more expertise. Using the ZPD as an analogy, we propose a new construct to describe those problems, which cannot be solved by individuals alone but which are possible to solve as a group - something we call the *zone of communal possibility (ZCP)*. Within this zone, we have seen examples of competitive (FoldIt, cited in Koepnick et al., 2019), asynchronous (Galaxy Zoo, cited in Malone, 2018), and collaborative (Idea Connection, cited in Baltzersen 2022) approaches to collective intelligence. The common thread across these examples is the collection of individual minds working together on a single problem. Researchers have demonstrated that groups of humans are able to solve problems which were previously unsolvable - due either to difficulty or size - simply by effectively distributing their efforts (Koepnick et al., 2019; Malone et al., 2009; Parslow, 2013; Rutherford et al., 2020).

Previous research has investigated the nature of distributed knowledge-construction activities (Dunbar, 1997). In this paper, we introduce a theoretical framework for characterizing the nature of distributed knowledge-construction activities and highlight the impact of interactions between individuals and ideas. The framework can ultimately be used to build computational models to help us understand the structure and dynamics of knowledge-construction activities, which are widely distributed across space and time.

Theoretical Foundations

Our theoretical framework is a synthesis of two existing theoretical frameworks, one characterizing the nature of formal knowledge-building activities, the other characterizing the collaborative nature of cognition.

Epistemic forms and games

Epistemic forms and games is a theoretical framework developed by Collins and Ferguson (1993) to characterize the formal knowledge-building work of scientists and scholars in non-scientific domains. The general idea is that scholars build new knowledge through epistemic games and that these games are guided by epistemic forms. Epistemic forms and their associated games correspond with particular research questions. In playing the game, *scientists enact moves*, such as adding or removing items, combining or splitting items, or substituting one item with another. While research has shown that formal knowledge construction is often a distributed process (Dunbar, 1997), the epistemic forms and games framework does not include machinery for explicitly characterizing this aspect of the work.

Distributed cognition

In his (1995) seminal work, Edwin Hutchins described cognition as a distributed phenomenon, dependent upon not just an individual brain, but upon other individuals, tools, and the environment in which cognition happens. Tools (such as a map or a calculator) allow for a distribution of cognitive work across time. These tools change over time and serve as repositories of knowledge, reducing the amount of work required to solve problems. As Baltzersen (2022) points out, information travels with artifacts. Even working 'alone' we can distribute the work across time by preparatory work or offloading cognitive tasks to our devices.

Distributed epistemic games

In the present work, we introduce the idea of *distributed epistemic games* (DEGs), which views epistemic games through the lens of distributed cognition. These games are played collectively by individuals with varying levels and domains of expertise, who therefore bring different knowledge (including knowledge of different epistemic forms) to the group task. The collective game will therefore reflect the interaction of games driven by these different forms. Additionally, the game may be distributed across location and time.

Because DEGs are not bound by constraints of space, time, and mind, they support larger numbers of participants and interactions. In the group interactions, we can see the process of "computation itself" (Hutchins, 1996, p. 283), or the thinking process itself (Hutchins, 2008, p. 2011). Following this line of reasoning, a larger number of interactions (as we see in a DEG) means there is more thinking happening around the problem. DEGs have a critical relationship with the *zone of communal possibility* (ZCP). DEGs coordinate efforts across individuals, time, and space in order to increase both the size of the ZCP as well as the knowledge available within it. DEGs are how groups of individuals work *within* the zone to solve problems through collaborative effort.

Our framework can be used to model DEGs. This includes identifying the moves involved in a particular game, the forms underlying and driving those moves, and the organization of the moves across players, time, and space. In this paper, we introduce a construct we call a *tactic*: a collection of moves made in an epistemic game, which together serve a larger purpose. In chess, masters will play multiple tactics, each of which is intended to add a threat to the opponent and advance the player toward victory. In DEGs, the intent is not to threaten an opponent, but to take multiple paths towards the goal of the larger game. While some of these tactics are deliberately planned, others emerge as a result of the interactions between individuals. Below, we identify the moves comprising a particular tactic that emerged in the distributed knowledge-building work of a network of individuals (n > 39), as they collaborated to solve a complex mathematical problem.

Methods

We use our distributed epistemic games framework and a microgenetic grounded approach to model the collaborative knowledge-building of individuals who came together in a unique way to solve a complex problem referred to by the group as *polymath1*.

This first Polymath project was proposed on the blog of a prominent mathematician (Gowers, 2009). The initial blog post posed the question of whether a group of individuals could engage in massive and collaborative problem solving. The problem chosen was to create a proof for the density Hales-Jewett problem (Polymath, 2012). The group's attempt at collaborative problem-solving was both mediated by and recorded in a temporal sequence of blog posts. Comments that made a contribution to the proof were numbered by users, so that they could be easily referenced. A total of 39 distinct users (29 of whom could be identified) contributed at least one numbered comment to the overall process (Cranshaw & Kittur, 2011). These users had a large range of expertise in their field as measured by the number of refereed publications. Several participants had no published work before engaging with the Polymath project, while a handful had hundreds of publications.

Data analysis

Building on Hutchins (2008), we are particularly interested in the interactions between individual contributors, which were captured by the comments and responses on the blog posts. A subset of the larger data set was selected by the research team for a closer analysis as it was determined to be particularly interesting with respect to interactional moves. This section - initially identified by the phrase "I can't see a flaw in your reasoning. If it's correct, then it shows something rather interesting" - was expanded as the research team worked backwards and forwards from that phrase to isolate interactions leading to and stemming from it.

Ultimately, the team ended up with a subset of 21 comments to review and code using a microgenetic grounded approach (Glaser & Strauss, 2017; Siegler, 2006). Individual posts were analyzed for potential moves and the larger structure of the temporal and inter-individual relationships of the moves made during the discussion segment was analyzed to provide insight into the way moves facilitated the generation of new knowledge.

Findings

We identified a collection of interactions as an *emergent tactic* (one which is not planned but emerges through interactions), which we have named the *pivot*. In the *pivot*, a monologue is interrupted resulting in an increase in interactions between members of the group. Within the *pivot*, we have identified the following moves:

- *Monologue*: In this move, there is consistent, relatively undisturbed, progress along a train of thought. While this comes from a single author in our selected example, it is possible to have this process carried out by multiple participants. The distinguishing characteristic is that it is consistent (or very nearly so) *progress along the same trajectory of thought*.
- *Interruption:* In the interruption, an engaged participant *poses a question which interrupts an ongoing thread.* The author has not responded to the most recent post, continuing the voice, topic, or trajectory of the monologue. The interruption problematizes a part of the thinking expressed in the monologue, which no one has thus far given attention. The interruption therefore challenges assumptions. In this particular interruption (Figure 1), the author seems to expect that the answer to his "dumb question" is already known, perhaps known well enough to make the question seem silly to more knowledgeable collaborators.

Figure 1
The Interruption

Can someone help me with this dumb question?

Suppose $A = B$ are the family of sets not including the last element n. Then A and B have density about $1/2$ within $KN_{n,n/2-k/2}$. (We're thinking $k(n) \to \infty$, $k(n)/n \to 0$ here, right?) It seems that the fraction of Kneser graph edges which are in $A \times B$ is about k/n, which is "negligible". So we should be able to delete any small constant fraction of vertices from $A = B$ and make it an intersecting family. But A is 100% of the Kneser graph $KN_{n-1,n/2-k/2}$, and doesn't the largest intersecting family inside such a Kneser graph have density only around $1/2$?

- *Response:* Someone in the group responds to the interruption. If the monologue continues without acknowledging the interrupting move (as occurs at other points in the larger project), then the *pivot* tactic has not emerged. In this particular response (Figure 2), we see the cognitive impact of the interruption, which challenged the assumptions inherent in the problem.

Figure 2
The Response

[redacted] all I can say is that I can't see a flaw in your reasoning. If it's correct, then it shows something rather interesting. I couldn't get [redacted] argument to work unless I assumed that degrees were very small rather than just small, and your example suggests that it's actually false when you merely assume that the degrees are a negligible fraction of the maximum possible. In your example, the degree of a vertex in A is still large, even if it's proportionately small, so there's still some hope that [redacted] argument is correct and adaptable to DHJ.

Now I must stare at the argument that I produced in 308 and try to work out what's going on.

- *Increased Interactions:* The final condition of the *pivot*, is an increase in interactions between individuals and a branching of thought processes. One of the ways to measure this increase in interactions is to look at the change in voices before and after the interruption (Matthews, Nguyen, & Swanson, 2023). Before the interruption there is a long monologue (10 distinct posts/comments) with a single voice. After the interruption the voice changes eight times in the next ten comments - showing a drastic increase in interactions.

Discussion

This paper introduced a new framework, which we call *distributed epistemic games*, for making sense of collaborative knowledge-building processes. The framework integrates ideas from two existing frameworks: *epistemic forms and games* and *distributed cognition*. We illustrated how the framework can be used to model the joint intellectual work of a group of mathematicians focused on solving an "unsolvable" problem. We identified and described a specific emergent tactic - *the pivot* - in terms of the individual moves of which it was composed and the increase it causes in the number of interactions among group members. Tying into the theory of distributed cognition, these increased interactions represent an increase in the knowledge-building activities of the group.

Without the affordances of computers, internet, and blog posts, the *distributed epistemic game* enacted in the Polymath Project would not have been possible, and the problem may have remained unsolved. By understanding this game, we can design environments, exercises, and games to solve more of the unsolvable problems by working together and extending our collective *zone of communal possibility.*

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