Investigating the Resources Framework through the Lens of Analytic Autoethnography: Analyzing Research Questions and "Resource" Grain Size

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There has been a recent trend in the application of fine-grained constructivist frameworks such as the resources framework; however, the resources framework has been operationalized in a variety of ways, particularly regarding analytic choices. In this work I seek to further discussions surrounding theory use and the ways frameworks may inform (1) research questions and (2) data analysis. Using an analytic autoethnographic approach, I characterize the variation in the application of the resources framework in my own work (n=10). This allows me to provide specific examples without evaluating the quality of colleagues' research, as well as contextualize the research within my experiences and within the broader norms of the chemistry education research community. To this end, I discuss alignment between the research questions and the resources framework and demonstrate variation in how "cognitive units" were operationalized. As an implication, suggestions are made regarding future work using the resources framework.

Keywords: theory; cross-disciplinary; research questions; methodologies

Background

Rationale and Scope

This work is part of a broader interest in furthering a dialogue related to methods and theory use in education research, which is of interest to the RUME community (Haas et al., 2022; Melhuish & Czocher, 2022). Last year at RUME I presented on a preliminary report that focused on the presence and use of frameworks across discipline-based education research (DBER) articles (Rodriguez & Nardo, 2023); this work was recently published as a systematic review in *Chemistry Education Research and Practice* (Rodriguez et al., 2023). As part of this review, we noted the potential for frameworks to connect DBER fields, "Therefore, it is more than shared disciplinary skills, language, and concepts that connect DBER communities. We are connected by theories and frameworks related to concerns such as how students learn and how to promote conceptual change." (Rodriguez et al., 2023). Illustrating the potential bridging connection afforded by theory, we noted research articles in the review sample across chemistry (Kelly et al., 2021; Parobek et al., 2021; Watts et al., 2021), mathematics (Abu-Ghalyoun, 2021), and physics (Barth-Cohen et al., 2021; Goodhew et al., 2021; Robertson et al., 2021) that used fine-grained constructivism as the theoretical framework. Nevertheless, although frameworks may be used across fields, there may be variation in their application. This work focuses on variation in theory use *within* a field (chemistry education research, CER), focusing specifically on analyzing my work that utilized the resources framework.

To this end, this work is guided by the research question: Across n=10 research articles involving the application of the resources framework to investigate undergraduate chemistry students' reasoning, what trends emerge related to the ways the resources framework informs: (1) the research question(s) and (2) analytic decisions?

Resources Framework

In brief, the resources framework is a constructivist-based theory used to model the nature and structure of knowledge, emphasizing the "fine-grained" and context-dependent nature of knowledge and describing the mechanism of conceptual change involving the gradual restructuring of a network of cognitive units ("resources") (diSessa & Wagner, 2005; Elby, 2000). For a theory of learning to be useful for education researchers it must: support prediction, possess explanatory power, be applicable to a broad range of phenomena, help organize thinking about phenomena, serve as a tool for analysis, and provide a language for communicating about learning (Dubinsky, 2001; Schoenfeld, 1998). I have found the resources framework to meet these criteria, using the framework to predict and explain patterns in student responses across contexts, informing how I think about students' reasoning, and influencing how I analyze data. Nevertheless, to improve teaching and learning we need to further refine the methods and theories that inform how we conduct research, employing an analytic agenda that emphasizes theory-building and the evaluation of theory.

Analytic autoethnography

Generally, ethnography is a field of study that emphasizes interpreting culture and its products, with autoethnography highlighting and leveraging the experiences of the researcher in this process (Adams et al., 2017). Acknowledging variation in the goals for studies within autoethnography, Anderson (2006) highlights a subgenre called analytic autoethnography. Here, the modifier *analytic* is used to draw attention to research aims focused on the analysis of empirical data that contributes toward theory development. To this end, the intended output of this work is a refined understanding of how to model cognition with a practical concern related to the ways it informs project scope and its application in data analysis. I view this as personally relevant in my application of theory but also seek to provide support for other researchers, particularly new and emerging researchers.

In the current study, the culture that serves as context for this work is the CER community of practice. The boundaries of a community of practice are defined through shared goals and norms, but these boundaries can often be fluid and complex (Wenger, 1998). This is especially true given the connections made between communities through boundary objects (e.g., journal articles) and brokers (e.g., researchers attending conferences), which could result in a "constellation" of interconnected communities of practice (p.127).

Data Collection & Analysis

For the purposes of this report, I narrowed the scope of the sample to include research articles involving the analysis of undergraduate chemistry students' reasoning where the resources framework was explicitly discussed as the theoretical framework (n=10) (Bain et al., 2018, 2019; Rodriguez et al., 2018; Rodriguez, Bain, Hux, et al., 2019; Rodriguez, Bain, & Towns, 2019; Rodriguez, Bain, Towns, et al., 2019; Rodriguez, Hux, et al., 2019; Rodriguez, Bain, et al., 2020; Rodriguez et al., 2021; Rodriguez & Towns, 2019). Analysis was guided by the research question presented above emphasizing the research question(s) and analytic decisions of the articles in the sample.

With regard to analyzing the research questions in the sample, I applied a framework that was developed in the context of ethnography (Spradley, 1980). The framework describes nine dimensions an ethnographer should attend to when collecting observational data: *space* (physical location), *object* (physical or cognitive entities), *actor* (individuals involved), *action* (behaviors and activities carried out by individuals), *time* (sequencing in a process), and *goal* (individuals' aims). Here, *object* has been adapted to include not just the physical entities but also cognitive or mental entities to afford a focus on students' knowledge and reasoning, as suggested by Melhuish and Czocher (2022); also, *act*, a*ctivity*, and e*vent* will be collectively described as *actions* for this work because the distinction between these types of observable behaviors is less relevant here. As discussed by Melhuish and Czocher (2022), this framework serves as a useful tool for discussing qualitative research questions, and in this work, analysis focused on the presence of different dimensions in the phrasing of the research questions, as well as the nature of the research question phrasing in relation to exploring relationships between dimensions and its connection to the resources framework. In terms of the analytic decisions expressed in the sample, analysis focused on the ways the framework was operationalized with an emphasis on the "size" of the identified resources. Additional analysis involved inductively grouping articles based on patterns related to the research questions and grain size. Throughout this process I engaged in reflexivity, which contributes to trustworthiness and validity of claims (Vagle, 2009, 2018). As a member of the CER community of practice, I'm familiar with expectations related to theory use in research. I implicitly interact with these norms as a producer (when publishing CER articles, presenting at CER conferences, etc.) and consumer (when reading CER articles, listening to presentations at CER conferences, etc.) but I also explicitly communicate these norms as an evaluator (when reviewing articles for a journal). The specific examples of articles discussed in the next section were selected to maximize variation, and I encourage interested readers to reference the articles if additional context is needed.

Preliminary Findings

Research Questions

Across the sample, the research questions tended to involve slight variations of the *actor-action-object* triad, where the stated goal was to elicit students' (*actor)* chemistry knowledge (*object*) using an interview task (*action*). References were not made to the other dimensions (*space*, *time*, *goal*). For example, in Rodriguez et al. (2021), our research question used problem-solving (*action)* as way to characterize students' (*actor*) understanding related to emergent properties and molecular behavior in a system (*object)*, *How do students use assumptions regarding system ontology to solve enzyme kinetics problems on an exam?* According to Melhuish and Czocher (2022), research questions that follow this pattern tend to have a singular focus and suggest a list as the research outcome. Although there was some variation with the research questions, this involved: an implicit reference to the *action* (the task is unspecified) – e.g., *How do students reason about rate constants in chemical kinetics?* (Bain et al., 2019); and multiple *objects* identified related to an interest in students' blending of chemistry and mathematics knowledge – e.g., *In what ways do students use mathematics in combination with their knowledge of chemistry and chemical kinetics to interpret concentration versus time graphs?* (Rodriguez, Bain, Towns, et al., 2019). The latter example moves closer to a relational focus that emphasizes connections between dimensions in the research question (Melhuish & Czocher, 2022).

Grain Size

As discussed by Wittmann (2006), resources can be described as fractal in nature: a cognitive unit described as a *resource* could be divided into a cluster of smaller resources. This is consistent with how I've observed the resources framework used in my work and others' broadly. Although this provides flexibility related to analytic decisions, this flexibility contributes to challenges with its application and defines the focus of this work. In the current work, thematic grouping resulted in the following grain sizes depicted in Figure 1: *p-prim*, *distributed element*, *concept projection*, and *frame*. Apart from *frame*, these terms are taken directly from the class of theoretical models outlined within knowledge-in-pieces (diSessa et al., 2016), the implications of which are discussed below.

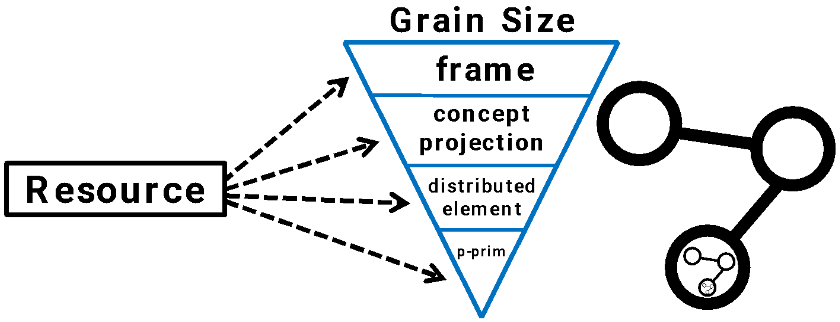

Figure 1. Variation in grain size observed in the articles.

Frames describe the expectations individuals have about a situation, which is important because of the ways epistemological frames may mediate the activation and use of knowledge (Redish, 2004). *Concept projection* is a reference to coordination class theory, which defines a *concept* and the mechanism of conceptual change within the knowledge-in-pieces perspective (diSessa et al., 2016; diSessa & Sherin, 1998; diSessa & Wagner, 2005). Here, *concept* (or *coordination class)* is defined as the combination of an inferential net (network of knowledge elements) and extractions (features attended to); it is the coordination of the knowledge component and perceptual component that allows students to "see" a *concept*. In practice, a *coordination class* would be a large cognitive structure and individuals use a subset of that knowledge when solving a task, a *concept projection*. Additionally, *distributed element* is a reference to specific knowledge elements within a *concept projection*. Lastly, *p-prims* (phenomenological primitives) are the smallest functional unit within a fine-grain constructivist view, reflecting intuitive knowledge that is self-explanatory and developed based on experiences (e.g., *dying away* is abstracted based on the observation that physical phenomena such as motion or sound tend to dissipate over time). In the next sections I will provide examples, focusing on distinguishing between *distributed element* and *concept projection*.

In Bain, Rodriguez, and Towns (2019) we analyzed students' reasoning related to the rate constant (*k*, a parameter relevant when discussing equations related to chemical kinetics). Some examples of the resources identified are *rate and rate constant as directly proportional* and *k is defined by the Arrhenius equation*. What I would like to draw attention to here is that these cognitive units are all narrowly focused on the rate constant and are phrased as statements (inferential or propositional statements), which provide a certain level of specificity, negating the need for a formal code description. This focus and specificity make the resources too small to be a larger cognitive structure like a *concept projection,* but are larger than *p-prims*, thus, described here as *distributed elements*.

In Rodriguez and Towns (2019), we analyzed how students reason about competitive, non-competitive, and uncompetitive enzyme inhibition. In this case, the inductive codes reflect cognitive units that are broader and larger than the *distributed elements* discussed above: *competitive inhibition, mechanism*; *non-competitive inhibition, mechanism*; *uncompetitive inhibition, mechanism*. Each of these codes has a general description: "Student discusses what physically happens with this inhibitor in a general sense or at the molecular level". Here, the codes are not statements and phrases related to a topic, but rather terms referencing broad discussions. Other examples might be codes such as *equilibrium, acid-base reactions*, *chemical kinetics*, etc., where the code description emphasizes that students "discussed" this topic, as opposed to stating the specific details students articulated about the topic. In the study referenced here, each of the different inhibition types can be described as a different *concept projection.*

Discussion

Reflecting on the connection between the research questions in the sample and the resources framework, only listing resources does not leverage the potential power of fine-grained constructivist frameworks in making claims related to the nature and structure of students' knowledge and its dependence on context (i.e., span and alignment) and time (i.e., conceptual change) (diSessa et al., 2016). As part of this, for researchers interested in applying the resources framework, there is room for incorporating more considerations related to other dimensions and relational aims across these dimensions, such as emphasizing how students' knowledge structures change over time (e.g., *How do chemistry majors' knowledge structures related to reaction rate change as they move through the undergraduate chemistry curriculum?).*

Regarding resource grain size, my plan for this analysis was to provide theoretical clarity related to the resources framework. I initially planned on avoiding making claims related to discussing the relationship between the knowledge-in-pieces and resources frameworks, but I found the language from knowledge-in-pieces to be helpful for describing the variation within the resources framework. According to diSessa (2016), the resources framework builds on knowledge-in-pieces providing language to discuss general nodes with varying structure and function within a knowledge system, but "resources are not particular kinds of knowledge elements" (p.58). Aligned with this, I discussed above that a resource could be different types of knowledge elements: a *p-prim*, *distributed element*, *concept projection*, or *frame*. Given a resource can vary in, for clarity, it is important that researchers are very clear in describing the scale of the knowledge they are analyzing. This does not necessarily have to involve the use of the terms discussed above, but detailed descriptions are important, such as "We are identifying resources at the level of evaluating students' inferential and propositional statements". As a disclaimer, these discrete resource sizes are just a few observable sizes within the data analyzed, and although they have a specific rank order, these are not all the possible grain sizes and the scale or distance between these levels are not necessarily equal. Moreover, there could also be dynamic interplay as multiple scales are considered, such as analyzing *frames* of individuals and groups (Conlin & Hammer, 2016).

Lastly, as a practical consideration, depending on choices related to the grain size in analysis there may be some drawbacks. For example, the resolution provided by coding at the *concept projection* level is too coarse to allow discussions regarding the connections students' make within a concept, with additional analysis needed (e.g., constructing resource graphs from a line-by-line analysis of an interview since the coded resources are too broad to afford claims about the structure of students' knowledge). On the other hand, the challenge with analysis at the *distributed element* level is that coding individual students' responses may be too idiosyncratic, resulting in concerns related to saturation of themes and workload when looking at large samples related to student responses on open-ended surveys and exam questions. Nevertheless, narrative coding and smaller samples involving selected episodes and cases (Rodriguez, Stricker, et al., 2020) aligns more with the approach toward knowledge analysis described by diSessa et al. (2016). Balancing the analytic tensions with the scope reflects on area warranting further inquiry.

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