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Toulmin's argument pattern as a "horizon of possibilities" in the study of argumentation in science education

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Abstract Kim and Roth (this issue) purport to draw on the social-psychological theory of L. S. Vygotsky in order to investigate social relations in children's argumentation in science topics. The authors argue that the argumentation framework offered by Stephen Toulmin is limited in addressing social relations. The authors thus criticize Toulmin's Argument Pattern (TAP) as an analytical tool and propose to investigate the genesis of evidence-related practices (especially burden of proof) in second- and third-grade children by studying dialogical interactions. In this paper, I illustrate how Toulmin's framework can contribute to (a) the study of "social relations", and (b) provide an example utilizing a theoretical framework on social relations, namely Engeström's Activity Theory framework, and (c) describe how we have used the Activity Theory along with TAP in order to understand the development of argumentation in the practices of science educators. Overall, I will argue that TAP is not inherently incapable of addressing social relational aspects of argumentation in science education but rather that science education researchers can transform theoretical tools such as Toulmin's framework intended for other purposes for use in science education research.

Lead editor: K. Jaipal-Jamani.

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Kim and Roth (this issue) claim to draw on the social-psychological theory of L. S. Vygotsky in order to investigate children's argumentation as social relations. They do so by investigating the genesis of evidence-related practices (especially burden of proof) in second- and third-grade children. The findings show "(a) a capacity of connecting claim and evidence/responding to the burden of proof and critical move varies and (b) that teachers play a significant role to emphasize the importance of evidence but experience the difficulties of removing children's favored ideas during the turn taking of argumentative dialogue". The authors argue that the argumentation framework offered by Stephen Toulmin is incapable of addressing social relations. Authors thus criticize Toulmin's Argument Pattern (TAP) as an analytical tool and propose to investigate the genesis of evidence-related practices (especially burden of proof) in second- and third-grade children by studying dialogical interactions.

In this paper, I want to illustrate the affordances that Toulmin's framework have for the purposes of science education research particularly in the context of social relations surrounding argumentation. I will do so by (a) questioning what is meant by "social relations", and (b) provide an example utilizing a theoretical framework on social relations, namely Engeström's Activity Theory framework, and (c) illustrate how we have utilized the TAP framework in relation to an Activity Theory analysis. Overall, I will argue that TAP is not inherently incapable of addressing social relational aspects of argumentation in science education but rather science education researchers can potentially transform theoretical tools intended for other purposes for use in science education.

Critique of Toulmin's argument pattern: is it justified?

Many authors including Kim and Roth (this issue) discuss how science education researchers have attempted to understand students' argumentation skills through various applications of argumentation in conversational and written arguments. Kim and Roth illustrate how many studies on argumentation adapted TAP to develop and analyze students' understandings of argumentation structures and levels of reasoning (e.g. Erduran, Simon, Osborne 2004). Toulmin (1958) proposed a definition of argument based on the components of claims, grounds, warrants, backing for warrants, rebuttals, and modal qualifiers (Toulmin 1958). In reviewing Toulmin's framework, Kim and Roth (this issue) provide a series of criticisms to highlight why TAP is not suitable as a framework for their purposes of identifying social relational aspects of argumentation. For example, they cite that TAP (a) is linear and technical when adapted as a sole analytical framework in research (Macagno and Konstantinidou 2013); (b) presented difficulties in the ambiguity of coding schemes (Kelly and Takao 2002); (c) proved to be problematic for analyzing students' argumentation encountering difficulties in coding between data and warrants and warrants and backings (Erduran, Simon, Osborne 2004); (d) does not sufficiently explain the dynamics of epistemic and social criteria of argumentation (Nussbaum 2011). Simply coding students' argumentation with TAP schemes makes it a challenge to understand the criteria of claim acceptance or rejection, implicit premises and standpoints, and the dynamics of social interactions and presumption that are often present in argumentative discussions (Nielsen 2013). The authors continue that

> As a result, analyzing with TAP schemes and any analytical models for high-level writing skills might not sufficiently explain how children learn to evaluate evidence, persuade and are convinced by others, and reach conclusions when their ideas are

challenged in the classroom, especially younger children in elementary schools. Given that studies of argumentation explained that even students in middle and high schools demonstrated the lack of high level components of argumentation such as warrants and backing (e.g. Sandoval and Millwood 2005), analyzing young children's argumentation by adapting the TAP analytical framework might not provide us meaningful understandings of young children's argumentation skills. As a result, there is a paucity of studies focusing on early elementary school students' argumentation in school science.

While Kim and Roth's criticism of TAP is justified in relation to the cited examples, the broad generalization about the limited appeal of TAP in dealing with social relations aspects of argumentation is not founded. For example, there is evidence in our work (Lazarou, Erduran, Sutherland 2017) that TAP can indeed be a useful framework in highlighting the social aspects of argumentation. I will thus turn to an illustration of how we have used TAP in conjunction with a socially informed theoretical framework proposed by Engeström (1987) in subsequent paragraphs. I want to start by questioning Kim and Roth's (this issue) notion of "social relations" as applied to argumentation in children's talk. The authors give the following descriptions when they describe social relations:

> The classroom talk produces {claim | evidence} and {claim | evidence | evaluation} units that most frequently are spread across multiple speakers. Sometimes however, these units already are found in the statements that individual children made. We observe the refutation of claims by means of evidence that do not match the claims. The evaluation of {claim | evidence} units was evident throughout the turn-taking sequences. The burden of proof also was observed. Instead of suggesting new evidence to refute a claim, a statement—articulated by some and heard by others— raised doubt and resulted in asking if dragon fruits had the parts that a child was unsure about. Others came to be invited, by a shift in the burden of proof, to support the counter-claim with better evidence. This type of shifting the responsibilities of proving one's claim was shown when children found mismatching evidence or when the strength and validity of {claim | evidence} units were questioned.

It is difficult to see from these descriptions what is supposed to be socially construed in the analysis. The primary guiding conceptual framework still seems to be based on Toulmin's framework given the extensive reference to key words such as 'claim', 'evidence' and 'refutation'. The authors' central guiding concept of "burden of proof" in the definition of social relations does not stem from a social theory as such but rather from an argumentation theory perspective. What exactly are the social relations highlighted here? What theoretical framework on social relations is being applied to illustrate social relations? How are Vygotsky's theoretical ideas used? Beyond the generic and theoretical review of sociocultural perspectives, it is difficult to see how the authors have actually framed the methodological framework on Vygotsky, or indeed how the main findings relate to Vygotsky's ideas.

"Activity Theory" as a framework for studying social relations

Consider, in contrast, an approach that is informed by a robust theoretical framework on social relations such as "Activity Theory" (Engeström 1987). In this section, I will review the definition and main components of Activity Theory and subsequently turn to a

discussion on how we have used it as a framework to understand, in conjunction with TAP, how a community of science teachers has dealt with the inclusion of argumentation in science teaching. According to Engeström's (1987) activity theory, human praxis is realized in the form of activities, as individual actions are insufficient to explain human behaviour and may appear meaningless outside the collective activities in which they occur. Activities comprise of actions that are directed towards a specific goal, even though they are still stimulated by the activity's motive (Leont'ev 1978, 1981). Actions comprise of operations that relate to the conditions that enable their materialisation and may be considered as automatized or routinised actions. Engeström (1987) expanded the initial approach of the concept of the "activity" by realizing activities as historically accumulated, multi-voiced, object-driven systemic wholes that can be portrayed by using the activity system model (Fig. 1).

In Lazarou, Sutherland and Erduran (2016), we argued that the practice of argumentation instruction may exist not only as an action but also as a discrete systemic activity within the broader activity of science education. 'Argumentation' as the main motive of this activity system, is the object of the activity and can be defined as the skill that students should have or attain in order to support a claim or for making links between facts they learn or for transferring the attained knowledge into instances of their everyday lives. In a related paper (Lazarou, Erduran, Sutherland 2017), we illustrated that regardless of the initial definition or meaning given to 'argumentation' as the object of the activity, what this concept means to stakeholders may change during the various phases of a social event, acquiring different identities and definitions based on stakeholders' needs and motives observed in their real environment. As objects are conceptualised and constructed by actors, who are functioning not as isolated units but are interacting in a collective, spatial and temporal way, they seem to be acquiring "*historical dynamics and trajectories of their own*" (Engeström 2005b, p. 93). Without the cultural-historical construction and content of objects, Engeström (1995) argues that understanding of activity and cognition remains formal and superficial.

We described how Engeström's activity theory, a social theory by definition, can be linked to argumentation in science education in general and argumentation in particular (Lazarou, Erduran and Sutherland (2017). In order to illustrate how we have linked activity theory and argumentation, I will review some basic tenets of Engeström's framework further. Engeström highlights that the object of an activity should be considered as "*a project*
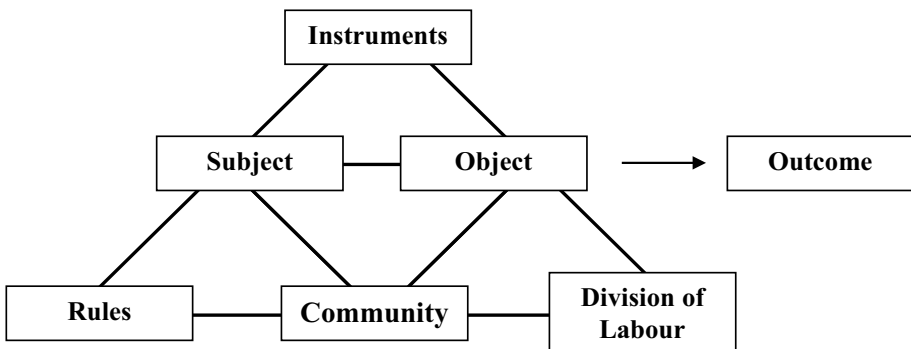

Fig. 1 The expanded activity system model (Engeström 1987)

under construction" (2005c, p. 184) and a constantly changing target that cannot be standardised or reduced to a series of conscious short-term actions (Engeström 2001, 2006); it may both be given to the participants and be anticipated, projected and reconstructed by them (Engeström 2001, 2005b). The object may be given as raw material to subjects who may re-interpret it and reshape it into a meaningful outcome or an entity of dynamic nature that is in a process of a constant movement towards new goals. In this sense, the object could be considered as deeply biased and subjective (Engeström 2006). Nevertheless, Engeström (2005a) emphasises that the object should neither be confused with the raw material nor with the end product but it should be realised as a trajectory which is realised as the complete process that takes place in order to advance from raw material to an attained, dynamically evolving entity. The reconstruction and reshaping of the object may be achieved through the participants' actions by choosing the appropriate properties that seem fruitful, as the object's multifaceted nature and inherent subjectivity allows a multiplicity of interpretations (Engeström 1995).

As each individual participant in the activity may perceive and personify the object in his own unique and meaningful way, multiple perspectives of how the object is realised may be noticed within the same activity (Engeström 1995, 2000). The object thus follows a course from an initial state of an "*unreflected, situationally given 'raw material' to a 'collectively meaningful object constructed by the activity system"* (Engeström 2001, p. 63).

In Lazarou, Erduran and Sutherland (2017) we reported a research project where we questioned the existing practice concerning argumentation in primary science education and assumed the unavailability of appropriate tools to support Year-6 students. Nevertheless, this initial assumption had to be addressed by socially expanding the study to engage more stakeholders, such as teachers, a science inspector and pupils. A detailed historical analysis of the existing practices concerning argumentation instruction was conducted so that the activity system of argumentation instruction in primary science education could be constructed and portrayed through the activity system model. Data collection included semi-structured interviews with five teachers teaching primary science, a semi-structured interview with the science inspector, and observation of four 80-min Year-6 science lessons in four other primary schools. Analytical methods included a qualitative discourse and content analysis of data collected, based on activity theory. The teachers and the science inspector who were interviewed, expressed certain recommendations, so that the identified contradictions could be resolved and a new vision for promoting argumentation in primary science education could be realised.

The notion of the 'springboard' from expansive learning theory (Engeström 1987) was used as an analytical tool. In particular, qualitative content and discourse analysis were conducted to help the participants envision a new way through which argumentation could be promoted in primary science education. The main contradiction that was identified regarding argumentation as a discrete skill and the realisation of argumentation as a skill of using or reporting on scientific knowledge. Teachers often expressed the concern during the meetings whether argumentation is indeed a discrete practice or skill that students may have or whether it is a skill of being able to evoke scientific content knowledge that they were taught during past lessons. To support this claim, they also drew examples from their lessons. Teachers made several theoretical and practical recommendations for overcoming this contradiction. Specifically, they emphasised the importance of pre-existing knowledge for engaging in argumentation. Pre-existing knowledge ought to be realised as a useful tool, a pre-condition and an inherent process of argumentation. Additionally, they suggested that argumentation should be recognised as a useful tool for helping students make the knowledge they possess more specific and overt (Lazarou, Erduran, Sutherland,

2017). Through the many discussions that took place during the meetings concerning the role of pre-existing knowledge, teachers managed to reconceptualise their own understanding about argumentation, suggesting that argumentation should be realised as a synergy between the awareness about the argument's structural components and knowledge about the specific scientific content.

Activity theory and Toulmin's argument pattern

Our identification of contradictions was thus informed by activity theory and our analysis used the narrative of this theory in capturing what was going on in the data. We identified additional contradictions where the teachers recognized TAP and the way it should be implemented in practice. In order to conceptualise these contradictions, TAP was considered as a commodified object, having both a use value and an exchange value; based on the theoretical definitions of these two values (Fig. 2). The use value of TAP refers to the value that it initially has as a useful product coined by Toulmin (2003) with the intention of satisfying the need of building solid and complete arguments while its exchange value refers to the value that the model acquires due to its exchangeability between individuals - in our study, between the teachers and the students, and the way it can be influenced by explicit or implicit social conditions. The reason for using these theoretical notions lay in "the fact that we wanted to exemplify the tensions that arose between TAP's initial value as a theoretical model and its acquired value when this model was exchanged in practice and was implemented in real teaching and learning conditions" (Lazarou, Erduran, Sutherland 2017, p. 11).

In our work, we acknowledged some tensions about the way that TAP was used in teaching and learning (Lazarou, Erduran, Sutherland 2017): (a) contradiction between the use value and the exchange value of TAP. This tension, as teachers reported, derived from the argument's multifaceted schematic form, the confusion that the warrant seemed to be inducing to students and confusion about what the starting point of the argument should be; (b) contradiction between the use value and the exchange value of the rebuttal and specifically, to the double bind that seemed to exist between the importance of the rebuttal as an integral part of a TAP argument, noted mainly by other teachers, and the difficulties and the confusion it created for students; and (c) difficulties that students faced with TAP was the difficulty in discriminating between the
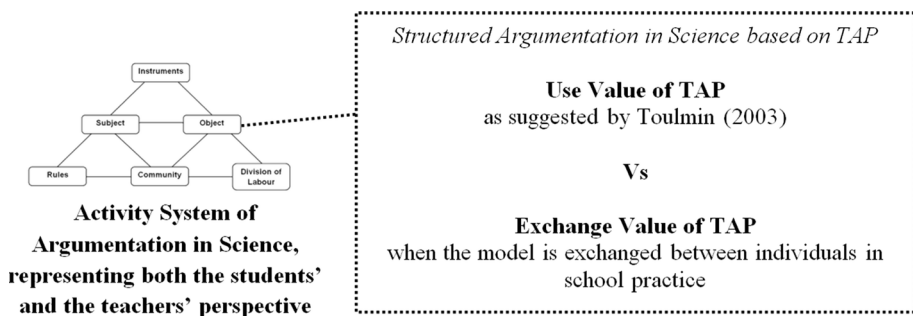

Fig. 2 Contradiction identified between the use value and the exchange value of TAP (from Lazarou, Erduran, Sutherland 2017, p. 61)

warrant and the data and in identifying and expressing a warrant. However, none of these tensions are necessarily about the particular model of argument. In all likelihood, any new model or definition of argument (or any new instructional approach for that matter) would have potentially presented similar tensions.

The object of the activity of argumentation instruction followed a revolutionary process. The way 'argumentation' was initially defined as the object of the activity was reshaped based on stakeholders' needs and motives into being defined as "structured argumentation" and then as "structured argumentation based on TAP". This reconceptualised object was introduced to the teachers as the given-new object of the activity of argumentation instruction at the beginning of second year of the project. Nevertheless, based on certain needs, motives and expectations, teachers seemed to personify this object in their own unique and meaningful way, by readapting what argumentation meant to them and by altering or readapting some of the features and elements of TAP; the alterations of TAP included an adaptation of the components' names or sequence, the way the argument could be presented, the structure of the argument's layout, the essence of the components and the order in which the components of the claim and the data could be expressed.

Based on the observed transformations that the object of the activity of argumentation instruction went through during two years and by drawing from the work of Engeström (1987), we argued that argumentation, seen as the object of the activity of argumentation instruction in science education, should not be seen as a stable and static entity in an activity system or as following a pre-determined course of evolution and development (Lazarou, Erduran and Sutherland 2017). Instead, argumentation should be realised as a trajectory, as a "*project under construction*" (Engeström 2005c, p. 184), a "*horizon of possibilities*" (Engeström 2005a, p. 10) and a dynamic entity that can evolve and change through time as it is meaningfully reinterpreted and reshaped by stakeholders within the activity system. Teachers' adaptations and recommendations in our research project, through which argumentation followed a revolutionary process, came to address their own needs and motives, in a process through which the development of these needs and consequently, the development of the object of the activity appeared as interrelated processes. The object was continuously being conceptualised and produced by the stakeholders based on certain needs that existed and was then distributed, exchanged and consumed in practice.

One of our recommendations for researchers was to be prepared to deviate from their initial realisation or definition of what argumentation is thought to be and allow the object of argumentation to gain a voice of its own (Lazarou, Erduran, Sutherland 2017). We noted that researchers should keep in mind that 'argumentation' as the object of the activity of argumentation instruction cannot be reduced to a passive and dead entity that is created by producers and be given to practitioners but that it "*only obtains its 'last finish' in consumption*" and "*becomes a real product only by being consumed*" (Marx 1973, p. 91). Therefore, the researcher's aim is to act in a way that will enable the object to be expanded and transcend its initial, expected boundaries towards new routes and forms that could reveal its developmental possibilities. Our work thus illustrated in detail the various transformations that the concept of 'argumentation' as the object of the activity of argumentation instruction in primary science education went through, by describing its historical evolution through the two-year research project. It has shown that the object of the activity, or what may be introduced as the given object in an activity, should not be considered as a static, stable entity but as an evolving concept and as a trajectory.

Conclusions and implications

In this paper, I have illustrated how we have utilized an activity theory approach proposed by Engeström (1987) along with TAP to understand argumentation in a social context. The robust theoretical framing of "social relations" through the use of Engeström's work complemented Toulmin's framework to elucidate to us, as science educators, how argumentation was being construed in a community of stakeholders. Bringing together different disciplinary contexts as diverse as social–historical psychology, philosophy and education remains a challenge but has no direct bearing on how synthesized perspectives may apply to different participants, be it adults or children. The fact that the participants were adults in our studies is, in essence, immaterial to the issue I am drawing on with respect to the lack of a clear theoretical lens in Kim and Roth's paper (this issue), particularly in relation to the framing of methodology. There are other accounts of how TAP can be adapted for science education purposes including in relation to methodological (e.g. Pabuccu and Erduran 2017) and instructional (Murphy and Erduran 2013) purposes. Even though argumentation in science education has drawn much attention in recent years as illustrated by trends in journal publications (Erduran, Ozdem, Park 2015), the social relations aspect of argumentation remains a relatively underspecified territory of research. This is no fault of the limitations of Toulmin's framework itself, which we ourselves have acknowledged (Erduran 2007). Citations in the leading journals in the social sciences, humanities and science and technology put Toulmin and his works in the top 10 among philosophers of science and philosophical logicians of the twentieth century (Loui 2005). Toulmin's *Uses of Argument*, and work in general, have been essential contributions to twentieth century thought. It will be wise to consider further the "horizon of possibilities" that Toulmin's ideas still seem to offer to science education.

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