Measuring Process and Outcome of the Scientific Argumentation in a CSCL Environment

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Abstract: This paper describes the conceptualization and operationalization of the scientific argumentation in a CSCL environment. An online platform is designed to support students' collaborative argumentation with diagram-based representations of argumentation based on Toulmin's (1958) Argumentation framework. Based on existing analytic frameworks of collaborative argumentation while accommodating the specific demands and characteristics of the target users and the environment involved, a conceptual framework and a group of indicators are derived for operationalizing the measurement constructs of the process and outcome of students' collaborative argumentation.

Keywords: collaborative argumentation, computer-supported collaborative learning, learning analytics, assessment for learning

1. Introduction

In recent years there is a shift in science education from focusing on exploration and experiment to the construction of argument and explanation (Duschl, Schweingruber, & Shouse, 2007). Argumentation is part of the practice of science for evaluating, refining and establishing new theories (Duschl, 1990). It has been widely recognized as an effective approach for science learning (e.g. Bell & Linn, 2000; Osborne & Patterson, 2011; Zimmerman, 2007; Zohar & David, 2008) as it helps students improve their conceptual understanding (Jiménez-Aleixandre, Bugallo Rodríguez, & Duschl, 2000; Bouyias & Demetriadis, 2012), understand the nature of science, promotes deeper learning of content (Nussbaum, 2008) and enhances knowledge creation (Erduran, Simon, & Osborne, 2004).

Many effective argumentation happens among students (Scheuer, Loll, Pinkwart, & McLaren., 2010) who engage in proposing, critiquing, coordinating evidence with claims to construct arguments and explanations, reflecting, and evaluating each others' ideas. Educational researchers have developed a good number of pedagogical approaches and tools to support students' collaborative argumentation (Scheuer, Loll, Pinkwart, & McLaren, 2010). However collaborative argumentation rarely takes place in school science classrooms. One of the critical issues is that teachers and students lack knowledge on what a desired collaborative argumentation is and how to work towards it. In such circumstances, the diversified measurement and assessment is needed to allow teachers and students to have a good understanding on the current status of the collaborative argumentation learning processes and its compatibility with the desired (Jermann & Dillenbourg, 2008), which in turn brings about more effective and efficient collaborative work.

This paper is to conceptualize and operationalize the collaborative argumentation in science classroom. It is part of a research project which attempts to support students collaborative argumentation in science (e.g., Clark & Sampson, 2007; Osborne, Erduran, & Simon, 2004; Zohar & Nemet, 2002) by providing automated assessments on students' performance through multi-dimensional learning analytics. It is believed that with appropriate conceptualization, operationalization and measurement of collaborative argumentation, productively collaborative argumentation processes can be engendered, and the students can be guided to function effectively and efficiently by monitoring, evaluating, and adapting their learning during collaborative activities (Gress, Fior, Hadwin, &Winne., 2010; Mora, Caballé, & Daradoumis, 2016).

The paper describes the operanalization of the counstrcuts of various aspects of collaborative arguementation including social participation, interaction patterns, argumentative knowledge construction process, cognitive artefacts and reasoning/epistemic patterns. Relating the process data to the outcome data, meaningful processes for productive collaborative learning can be identified. This will provide insights on relevant pedagogical design accordingly.

2. Literature Review

2.1 Argumentation and Learning

Argumentation is a key human skill that is used in a variety of domains and situations (Scheuer, Loll, Pinkwart, & McLaren, 2010). The production of coherent arguments to justify solutions and actions is critical to solving problems (Cho & Jonassen, 2002). The ability to evaluate and reflect on arguments and counter-arguments is an important component of critical and inventive thinking skills that can enable sound decision making and task performance (Quinn, 1997; Nussbaum, 2008). Argumentation is also viewed as a vital type of knowledge construction activity that can lead to knowledge advancement and improvement (Weinberger & Fischer, 2006).

There are argumentation frameworks and models developed which inform the study. One of the most widely used argumentation framework is Toulmin (1958) model which has been used by many researchers (e.g., Cho & Jonassen, 2002; Erduran, Simon, & Osborne, 2004; Jime´nez-Aleixandre, Rodriguez, & Duschl, 2000; Kelly, Drunker, & Chen, 1998; Kenyon & Reiser, 2006; Krummheuer, 1995; Osborne, Erduran, & Simon, 2004). The Toulmin (1958) Model is analytical and provides the structure of an argument which consists of six main components: claim, grounds, warrants, qualifiers, backings, and rebuttals. A *claim* is an assertion, or statement, about a belief or idea. *Grounds* are statements or reasons that support the *claim*. *Warrants* are an elaboration on the reasoning behind why the person believes their *claim* to be true. A *qualifier* provides strength and clarification to the *grounds* and *warrant*. With a *qualifier*, the claim is valid only during a specific circumstance. A *rebuttal* is a particular condition in which the *warrant* becomes void and the *claim* is not valid. While a *qualifier* can provide strength and clarification, the *backing* provides support to the *warrant* by stating why the *warrant* is acceptable.

2.2 Learning Analytics of Collaborative Argumentation

In existing literature on computer-supported collaborative learning (CSCL), a variety of inter-psychological mechanisms embodied in discourses that favor collaborative knowledge construction have been identified (e.g., conceptual controversies: Johnson, 1981; considering others' perspective: Järvelä & Häkkinen, 2000; formulating ones' own point of view: Webb, 1991; progressive discourse: Bereiter, 1994; Oshima, Oshima, & Matsuzawa, 2012; Scardamalia & Bereiter, 2003; exploratory dialogue: Mercer, 2000; Mercer & Littleton, 2007). The discovery and exploration of these pivotal processes for knowledge advancement provide the possibility of leveraging on online learning analytics, i.e. the measurement, collection, analysis and reporting of data about the learner and the contexts (Buckingham Shum & Ferguson, 2012).

Through discourse analysis, the presence or absence of the intended knowledge construction processes can be revealed, which can serve as good indicators for tracking and assessing whether the unfolding learning processes are productive or not from the perspective of co-construction of knowledge. There has already been some exploration that goes for this direction in the field of learning analytics research. For instance, Ferguson and Buckingham Shum (2011) have demonstrated that the attributes of exploratory dialogue such as challenges, extensions, evaluations and reasoning can be automatically identified within online discussion. Following this approach, the emergence and evolution of exploratory dialogues which are most desired by educators can be monitored.

Besides analyzing and visualizing the pivotal processes that can positively contribute to collaborative knowledge construction, the epistemic nature of reasoning enacted by students in the process of argumentation is to be evaluated in the project as well. This is a very important aspect for assessment as it can shed light on the type of reasoning that students use when they propose, support, evaluate and challenge ideas (Clark et al., 2007). Among the analytical frameworks developed for analyzing argumentation, quite a few laid their focus on the analysis of such epistemic moves made by students that can reflect the type of reasoning processes involved (e.g., Walton, 1996; Jime´nez-Aleixandre, et al., 2000). These frameworks can guide the design and development of indicators for measuring the application of reasoning skills and strategies employed by the students. Jimenez-Aleixandre, Rodriguez and Duschl (2000), for instance, established nine categories of epistemic operations (namely induction, deduction, causality, definition, appeals to analogy, exemplar, instance, attribute or authority, consistency with other knowledge, experience, commitment to consistency, or metaphysical, and plausibility) for understanding how students elaborate, reinforce, or oppose the arguments of each other. Analyzing the proportions of argumentative dialogue and epistemic moves made in the dialogue can help reveal how students approach argumentation. Comparing the reasoning\epistemic processes enacted by the students and those "desired" ones (enacted by "experts"), the attainments and gaps in students' work can be identified, and both quantitative and qualitative feedbacks can be provided to help teachers and students to adjust their following actions accordingly.

3. The CSCL Environment

The project developed a prototype of a computer-based collaborative argumentation system to support students' collaborative argumentation with diagram-based representations of argumentation (Chen, Looi, Xie & Wen, 2015) (see figure 1 for the system interface). On the diagram-based argumentation space, an argument refers to an organized set of argument elements represented by nodes and/or directed links. The specific types of argument elements adopted are in accordance with Toulmin's Argumentation Pattern (TAP) (1958, 2003). For pragmatic considerations (e.g., understandability of secondary school students) (Scheuer et al., 2010), the original TAP model is simplified. Three argument elements, namely claim, evidence for (support), and evidence against (rebuttal) are identified as the essential components of an ideal argument. These elements are represented by: 1) the type of Node: Claim vs Evidence and/or; 2) the type of directed Link: For vs. Against.

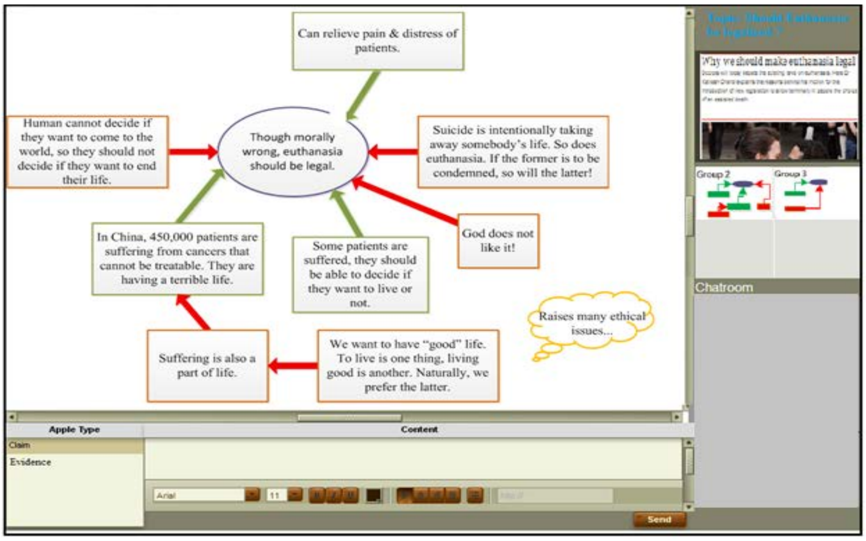

Figure 1. AppleTree System Interface

4. Conceptualization and Operationalization of Collaborative Argumentation

Existing analytic frameworks that are used for examining the quality of argumentation in different formats (e.g. dialogue-based vs graph-based) and with different focuses (e.g. the process vs outcomes of argumentative knowledge construction; the cognitive vs social processes of collaborative argumentation) were examined for the concepulisation of argumentation in this paper. This extensive search and research helped identify the critical dimensions of collaborative argumentation that deserve measuring and assessing. Then the dimensions and indicators that reflect our view on collaborative argumentation as a critical type of knowledge-construction discourse, a social practice that can lead to knowledge advancement (Clark et al., 2007). As widely acknowledged, the configuration of educational measurement should reflect not only the specific perspectives on learning but also the pedagogical goals and the environment structure characteristics (Clark et al., 2007). Figure 2 show the conceptual framework of the collaboratiev arugumentaion measurement. The collaborative argumentation can be measured from two aspects: social process and cognitive outcome. Basing on existing valid and reliable analytic frameworks of collaborative argumentation (e.g., Erduran, Simon, & Osborne, 2004; Toulmin, 2003; Weinberger & Fisher, 2006; Zhang, Hong, Scardamalia, Teo, & Morley, 2011) while accommodating the specific demands and characteristics of the user and the environment involved, a group of indicators were derived for operationalizing the measurement constructs.

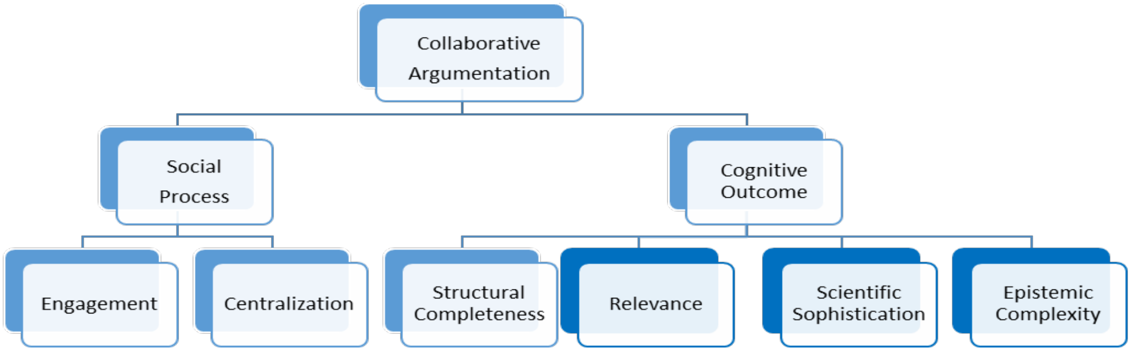

Figure 2. Meaurment Framework

4.1 Social Process

The social process assessment is about measuring the process of the collaborative knowledge construction. Engagement and Centralization focus on social participation and interaction process.

4.1.1 Engagement. Engagement refers to the frequency of contribution to the group work. The higher the frequency, the higher the level of engagement is.

4.1.2 Centralization. Centralization is the degree to which the group members equally participate in group interaction. It is measured by the inequality of interactions by different members within the group. The higher the inequality, the lower the centralization is.

4.2 Cognitive Outcome

The cognitive outcome assessment is concerned with the evaluation of the artifacts that a student or a group of students create when asked to articulate and justify claims or explanations. It reveals the advancement of scientific knowledge and the engagement in the epistemic practices in doing science (e.g., coordinating between theory and evidence; taking alternative perspectives into consideration) and the application of reasoning and epistemic strategies. Structural completeness, relevance, scientific sophistication and epistemic complexity are the four constructs identified for measuring the argument as the outcome.

4.2.1 Structural Completeness. Structural completeness is the presence of the essential structural components in an argument generated. The better an argument is, the more components are included. In the present context, an argument contains a claim, one (or more than on) evidence for, and more than one evidence against is regarded as a complete argument. There are 4 levels of measurement for structural completeness: Level 1 - one claim without any evidence; Level 2 - One claim with one "evidence for" OR one "evidence against"; Level 3 - One claim with one "evidence for" AND one "evidence against"; level 4 - One claim with more than one "evidence for" AND more than one "evidence against". The structural completeness of the argument diagram is computed by the sum of scores of all the arguments it contains.

4.2.2 Relevance. Relevance concers whether the evidence provided is related to the topic under argumentation and whether it can support the claim or the evidence that it is directed to. There are 4 leavel of measurment for relevance. Level 1 - Irrelevant information/facts; Level 2 - Some relevance but no logic coherence; Level 3 - Relevant and logic but not reflect the key points; Level 4 - Relevant and logic, and reflect the key points.

4.2.3 Scientific Sophistication. Scientific sophistication refers to the extent to which students have moved from an intuitive toward a scientific framework. Scientific sophistication represents the level of success a student has achieved in processing an idea at a certain complexity level. The higher the sophistication, the more scientific the idea that produced is. There are 4 leavel of measurment for *Scientific Sophistication*. Level 1 - Misconception; naive conceptual framework; Level 2 - Misconceptions that have incorporated scientific information but show mixed misconception/scientific frameworks; Level 3 - Basically scientific ideas based on scientific framework, but not precisely scientific; Level 4 - Scientific explanations those are consistent with scientific knowledge.

4.2.4 Epistemic Complexity. Epistemic complexity refers to the extent to which students make effort to produce theoretical explanations and articulations of hidden mechanisms central to the nature of science (i.e., providing and elaborating explanations or justifications) besides providing descriptions of the material world (i.e., providing unelaborated facts). Epistemic complexity represents the level of complexity at which a student\group chooses to approach an issue. Epistemic complexity of an argument element is measured by the cognitive effort taken to processing it as reflected in the content. The greater the cognitive effort, the higher the complexity is. There are 4 leavel of measurment for *Epistemic Complexity*. Level 1 - Unelaborated facts: Description of terms, phenomena, or experiences without elaboration; Level 2 - Elaborated facts: Elaboration of terms, phenomena, or experiences; Level 3 - Unelaborated explanations: Reasons, relationships, or mechanisms mentioned without elaboration; Level 4 - Elaborated explanations: Reasons, relationships, or mechanism elaborated.

5. Conclusion

The system is a knowledge representation tool where the structure of argumentation is explicitly represented to support students' collaborative argumentation. To better inform the teaching and learning practices, the measurement should reflect the critical aspects of the collaborative argumentation and addressing the need from teachers and students in classroom learning activity. The measurement indicators established reflect the commonly acknowledged view on collaborative argumentation as social processes that can enable knowledge construction and creation. The future work include validating the measurement framework and indicators by empirical studies in classrooms, and automating the human coding though social network analysis, natural language processing and machine learning technologies etc.

References

Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: Designing for learning from the web with KIE. *International Journal of Science Education, 22,* 797–817.

Bereiter, C. (1994). Implications of postmodernism for science, or, science as progressive discourse. *Educational Psychologist, 29*(1), 3–12.

Bouyias, Y., & Demetriadis, S. (2012). Peer-monitoring vs. micro-script fading for enhancing knowledge acquisition when learning in computer-supported argumentation environments. *Computers & Education*, *59*(2), 236-249.

Buckingham *Shum*, S., *& Ferguson*, R. (*2012*). Social learning analytics. *Educational Technology & Society, 15*(3), 3–26.

Buckingham Shum, S., Selvin, A. M., Sierhuis, M., Conklin, J., Haley, C. B., & Nuseibeh, B. (2006). Hypermedia support for argumentation-based rationale: 15 years on from {gIBIS} and {QOC}. In A. Dutoit, R. McCall, I. Mistrik & B. Paech (Eds.), *Rationale Management in Software Engineering* (pp. 111-132). Book Chapter, Springer Verlag.

Chen, W., Looi, C.K., Xie, W., & Wen, Y. (2015). Designing automated assessment FOR collaborative argumentation in Science classroom: A pilot study. In Lindwall, O, & Ludvigsen, S. (Eds.) *Proceedings of the 11th International Conference on Computer-Supported Collaborative Learning (CSCL 2015) Gothenburg Sweden* (pp. 533-538). Gothenburg, Sweden: International Society of the Learning Sciences.

Cho, K. L., & Jonassen, D. H. (2002). The effects of argumentation scaffolds on argumentation and problem solving. *Educational Technology Research and Development*, 50(3), 5-22.

Clark, D.B., & Sampson, V. (2007). Personally seeded discussions to scaffold online argumentation. *International Journal of Science Education, 29*(3), 253–277.

Clark, D. B., Sampson, V., Weinberger, A., & Erkens, G. (2007). Analytic frameworks for assessing dialogic argumentation in online learning environments. *Educational Psychology Review, 19*(3), 343-374.

Duschl, R. (1990). *Restructuring science education: The role of theories and their importance*. New York: Teachers College Press.

Duschl R.A. Schweingruber H.A. Shouse A.W. (Eds.). (2007). *Taking science to school: Learning and teaching in grades K-8.* Washington, DC: National Research Council.

Erduran, S., Simon, S., & Osborne, J. (2004). Tapping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education, 88*, 915-933.

Ferguson, R., & Shum, S. B. (2011). *Learning analytics to identify exploratory dialogue within synchronous text chat.* International Conference on Learning Analytics and Knowledge, Lak 2011, Banff, Ab, Canada, February 27 - March (pp.99-103). DBLP.

Gress, C. L. Z., Fior, M., Hadwin, A. F., &Winne, P. H. (2010). Measurement and assessment in computer-supported collaborative learning. *Computers in Human Behavior, 26*(5), 806–814.

Jermann, P., & Dillenbourg, P. (2008). Group mirrors to support interaction regulation in collaborative problem solving. *Computers & Education, 51*(1), 279–296. doi:10.1016/j.compedu. 2007.05.012

Järvelä, S., & Häkkinen, P. (2000). Levels of web-based discussion: Theory of perspective-taking as a tool for analyzing interaction. In B. Fishman & S. O'Connor-Divelbiss (Eds.), *Fourth international conference of the learning sciences* (pp. 22–26). Mahwah, NJ: Erlbaum.

Jime´nez-Aleixandre, M.P., Rodriguez, M., & Duschl, R.A. (2000). ''Doing the lesson'' or ''doing science'': Argument in high school genetics. *Science Education, 84*(6), 757–792.

Johnson, D. W. (1981). Student–student interaction: The neglected variable in education. *Educational Researcher, 10*, 5–10.

Kelly, G., J., Druker, S., & Chen, C. (1998). Students' reasoning about electricity: combining performance assessments with argumentation analysis. *International Journal of Science Education, 20*(7), 849-871.

Kenyon, L., & Reiser, B. J. (2006). *A functional approach to nature of science: Using epistemological understandings to construct and evaluate explanations*. Paper presented at the annual meeting of the American Educational Research Association, SanFrancisco, US.

Krummheuer, G. (1995). The ethnography of argumentation. In P. Cobb & H. Bauersfeld (Eds.). *Emergence of Mathematical Meaning.* Hillsdale, NJ: Erlbaum.

Mercer, N. (2000). *Words and Minds*. London: Routledge.

Mercer, N., & Littleton, K. (2007). *Dialogue and the Development of Children's Thinking.* Routledge: London.

Mora, N., Caballé, S., & Daradoumis, T. (2016). Providing a multi-fold assessment framework to virtualized collaborative learning in support for engineering education. *International Journal of Emerging Technologies in Learning*, *11*(7), 41-51.

Nussbaum, E.M. (2008). Collaborative, argumentation, and learning: Preface and literature review. *Contemporary Educational Psychology, 33,* 345–359.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in science classrooms. *Journal of Research in Science Teaching*, *41*(10), 994–1020.

Osborne, J. F., & Patterson, A. (2011). Scientific argument and explanation: A necessary distinction? *Science Education*, *95*(4), 627-638

Oshima, J., Oshima, R., & Matsuzawa. Y. (2012). Knowledge Building Discourse Explorer: a social network analysis application for knowledge building discourse. *Educational Technology Research and Development*, 60(5), 903-921.

Quinn, V. (1997). *Critical Thinking in Young Minds.* London: David Fulton.

Scardamalia, M., &Bereiter, C. (2003). Knowledge building. In J. W. Guthrie (Ed.), *Encyclopedia of education* (2nd ed., pp. 1370–1373). New York: Macmillan Reference, USA.

Scheuer, O., Loll, F., Pinkwart, N., & McLaren, B. M. (2010). Computer-supported argumentation: A review of the state of the art. *TheInternational Journal of Computer-Supported Collaborative Learning, 5*(1), 43–102. doi:10.1007/s11412-009-9080-x.

Toulmin, S. (1958). *The Uses of Argument*. New York: Cambridge University Press.
Toulmin, S. (2003). *The Uses of Argument (2nd ed).* Cambridge: Cambridge University Press.
Walton, D. (1996). *Argumentation schemes for presumptive reasoning*. Mahwah, NJ: LawrenceErlbaum Associates.
Webb, N. M. (1991). Task related verbal interaction and mathematics learning in small groups. *Journal for Research in Mathematics Education, 22*(5), 366–389.
Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers & Education, 46*(1), 71–95.
Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review*, *27*(2), 172–223.
Zohar, A., & David, A. (2008). Explicit teaching of meta-strategic knowledge in authentic classroom situations. *Metacognition and Learning, 3*(1), 59–82.
Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching, 39*(1), 35–62.
Zhang, J. W., Hong, H-Y., Scardamalia, M., Teo, C. L., & Morley, E. A. (2011). Sustaining knowledge building as a principle-based innovation at an elementary school. *Journal of the Learning Sciences*, *20*(2), 262-307.