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Pre-University Chemistry Inquiry Learning

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ABSTRACT
This research focuses on student inquiry learning in a simulated scholarly research. The design was based on a framework of six principles. One of the student activities, the peer review, was founded on activity theory. 428 groups of pre-university chemistry students from various countries participated. All students conducted, in small groups, an inquiry on fermentation at their schools. They wrote an inquiry report, did a peer review on another article and wrote a final article. Four groups of two students were randomly selected. Their peer review comments and articles were analyzed on the level of the student understanding of inquiry quality concerning five categories. The data were completed with in-depth group's interviews. It was concluded that student understanding was positively influenced with an exception for their understanding of reliability. Simulated scholarly activities can be founded on activity theory. The implications of this foundation regarding simulated scientific activities are discussed.

KEYWORDS: Design research, activity theory, pre-university chemistry inquiry learning

Resumen (Aprendizaje de la indagación química en el nivel preuniversitario)
Esta investigación está centrada en el aprendizaje basado en indagación dentro de un ambiente de investigación simulado. El diseño se fundamentó en un marco de seis principios. Una de las actividades de los estudiantes, la revisión por pares, se fundamentó en la teoría de la actividad. Participaron 428 grupos de estudiantes pre-universitarios de química de diversos países. Todos los estudiantes trabajaron en pequeños grupos y llevaron a cabo una indagación sobre fermentación, en sus escuelas. Los estudiantes escribieron un reporte de indagación, hicieron una revisión por pares de otro artículo y al final escribieron sus comentarios. Se seleccionaron al azar cuatro grupos de dos estudiantes. De éstos se analizaron sus comentarios de la revisión por pares y sus artículos. El análisis se llevó a cabo dependiendo del nivel de comprensión de indagación de los estudiantes, el cual consiste en cinco categorías. Los datos se complementaron con entrevistas grupales profundas. Con esto se pudo observar que, en general, la comprensión de los estudiantes fue positivamente influenciada con excepción de su entendimiento de la responsabilidad. Las actividades escolares simuladas pueden ser fundamentadas con la teoría de la actividad. Se discuten las implicaciones de esta fundamentación con respecto a las actividades científicas discutidas en este artículo.

Palabras clave: diseño de investigación, teoría de la actividad, aprendizaje de la química preuniversitaria mediante indagación

Investigación de diseño, teoría de la actividad, aprendizaje pre-universitario de química basado en la indagación

In many countries science education standards requires involvement of secondary school science students in inquiry-based learning (cf. National Research Council, 1996). By emphasizing scientific inquiry learning in science curricula, teachers and educational researchers are challenged to come up with practically and theoretically founded approaches that are essential for student inquiry learning (e.g. Bencze & Hodson, 1999; Kass & Macdonald, 1999; Krajcik et al. 1998; Lotter, Harwood & Bonner, 2007; Roth, 1996; Windschitl, Thomson & Braaten, 2008; Van Rens, Van Dijk & Pilot, 2004).

Educational research often responds to this challenge from two perspectives: students who do activities that resemble scientists' research activities (e.g. Driver et al. 1994; Van Rens, Pilot & Van der Schee 2010) or students who work at scientists' elbows (e.g. Barab & Hay, 2001; Lee & Songer, 2003; Bell et al., 2003; Van Rens et al., 2011). These studies are based on the assumption that students who either work on simulated research activities or at scientists' elbows will develop understanding about the practice of scientists, nature of science and scientific inquiry, as well as develop interest in and motivation for science.

However, in classroom settings science teachers often meet constraints in teaching scientific inquiry that really fosters students' scientific inquiry learning (c.f. Lunetta, Hofstein & Clough, 2007). Moreover, in educational practice not all science students have the opportunity of working at scientists' elbows, so it is proposed to study student inquiry learning when they are involved in simulated research activities.

To further address the issue of student inquiry learning in simulated research activities, this study investigates student understanding of quality in an inquiry when they perform an

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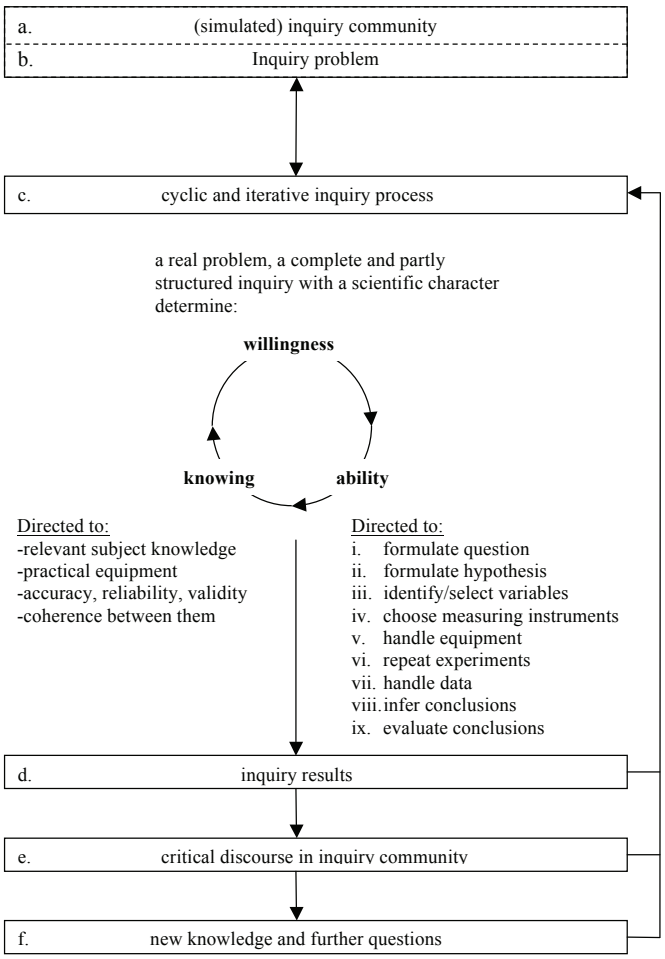

Figure 1. Framework of the six principles (a-f) for designing a simulated scholarly research.

inquiry module, the design of which is based on a theoretical framework that brings in activities that resemble authentic science research and is based on activity theory with regard to one of its components.

Theoretical framework

Designing simulated scientific research activities that are feasible for pre-university chemistry students in classroom settings requires collaboration with pre-university chemistry teachers (Kelly, 2003). The design of such activities should give the students an insight in the scientific research practice, so a framework of the activities in a scientific research practice is needed. Van Rens et. al. (2010) argue that the design of a simulated scientific research should be based on six principles: a) create an inquiry community; b) select an adequate inquiry problem; c) design a cyclic and iterative inquiry process related to student willingness, knowing and ability; d) share inquiry results; e) create critical discourse in the community; and f) share new knowledge and further questions (see Figure 1). This framework was used to design, in cooperation with five pre-university chemistry teachers, several chemistry inquiry modules: Traditional and modern soap: washing power; Cola and Teeth; Cool: design a cold pack; Salty or Ionic Liquids (Van Rens & Pilot, 2010); Biofuels; Chocolate; and Gastronomy. These inquiry modules are successfully implemented between 2003-2009 by a number of pre-university chemistry students reaching from 124 up to 663 and a number of pre-university chemistry teachers from 9 up to 34 respectively.

Scientific research includes peer review to create critical discourse in the science community. It has been used to determine academic merit for already several centuries (e.g. Larochelle & Désautels, 2002). The scholarly activity of peer reviewing can be taken as an example in order to concretize design principle (e), so that students have an opportunity to a critical discourse in the inquiry community.

In this study, scholarly peer review is considered as a human activity in terms of activity theory. This theory describes human activities with regard to the connection between scientific knowledge and social practice in a historical, cultural and societal sense (Leont'ev, 1978). Connecting these two creates relevance in the students' eyes and so gives them motives to tackle scientific problems and to make socio-scientific decisions (e.g. Hofstein, Eilks & Bybee, 2011; Holbrook & Rannikmae, 2007; Lemke, 2001; Roth & Lee, 2004; Van Aalsvoort, 2004).

According to Leontev (ibid.) human activities manifest on three levels: the level of condition-driven and routinized operations, the level of goal-driven individual or group actions and the level of motive or object-driven collective activities.

The latter level or the level of object-driven collective activities is frequently depicted as an activity system with seven components: subjects, community, object, outcome, division of labor, rules and tools. Such a system is described in a sense that activities of *subjects* or humans are oriented towards an *object* and transformed into an *outcome*. Moreover, activities are carried out by a *community* and are mediated by *tools*, *division of labor* and *rules* (e.g. Engeström et al., 1999; Roth et al., 2002; Kahveci, Gilmer & Southerland, 2008; Hsu et al., 2010).

An activity system seems to be appropriate for simulating the activity of scholarly peer review, because it provides a connection between scientific knowledge in scholarly peer review and a collective inquiry peer review practice.

For the scientific knowledge component in scholarly peer review, the knowledge is considered that transpires when scientists submit their work for publication to the science community. This reviewing process is traditionally based on criteria by which peers judge the quality of the literature review, the significance of the question, the accuracy of the method, the reliability of the results, and whether the presented data support the conclusions and implications (c.f. Baker, 2002). This knowledge is imbedded in an activity system where the *subjects* are students cooperating in groups of two or three and sharing the same *object* — peer reviewing a student inquiry article regarding a specific topic — in a distinct