

Learning By Doing: Cognitive Apprenticeship in Chemical Research

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Introduction

Studies of science-as-practice increase robustness of epistemology while assuming that scientists are simply cognitive agents in specialized communities in which (a) human judgment and representational use are exercised within research (Giere, 1992), (b) scientists' problem-solving strategies and representations, refined over the history of science, are sophisticated outgrowths of ordinary reasoning and representations (Nersessian, 1999), and (c) mental models are integral to reasoning and capable of illustrating dynamic cause and effect in real-world systems.

Theoretical Background

Cognition in science-as-practice is based on situated learning as a social process that occurs within a proficient community of practice. Novices progress from peripheral participation to full as they acquire the "street smarts" of that community. The facets of cognitive apprenticeship afford a participant's immersion and many opportunities for practice, reflection and discussion while solving community problems, while their progress is scaffolded by community mentors (Lave & Wenger, 1991).

Methodology

Three undergraduate novices, selected for a NSF Research Experience (REU) program worked in a 12-person organic synthesis lab where they were mentored. We used an ethnmethodological approach; the unit of analysis was the interactions of individual, context, and activity over time captured in 60 hours of video. Novices were interviewed about specific clips and overall experiences. Relevant vignettes were transcribed and analyzed.

Results

The learning environment was composed of three laboratories, laced with reagent bottles, heating mantles, vacuum pumps, fume hoods, chromatography equipment, reference books, and computers. Active researchers spent a disproportionate amount of time solving small problems that were inhibiting their progress on a project. Scientific reasoning, while involving induction and deduction, was more generally problem solving based on mechanistic models. New researchers gradually developed an ability to talk precisely and well but most talk was not articulate. Novices were given projects that were a part of the funded

research program. Novices began with little confidence in their ability to figure out problems, use instruments, and interpret data. They were wary of making judgments and decisions early on but acquired feedback through discussions and instrumental analysis that enabled growth.

Our studies of mentoring dyads revealed substantial communication problems. The gap was often within the zone of proximal development and resolvable, but frequently the gap wasn't bridged because neither realized that they were using similar words but not holding the same mental representation, e.g., a gap emerged over the results of nuclear magnetic resonance: (a) The novice did not notice an anomaly; (b) When the mentor pointed out the anomaly on the NMR spectrum, the novice became defensive; and (c) As the discussion continued the novice saw the anomaly on a macro level while the mentor meant the molecular level. Neither of them ever realized that differing representation levels were causing their communication frustrations.

Conclusions

Apprenticeship is not efficient but seems highly effective as a learning environment. Novices were stretched cognitively and motivationally as they struggled to understand their research, troubleshoot frequent problems, and communicate with mentors, whose procedural knowledge and reasoning were often tacit. Novices exhibited difficulty transferring course knowledge to research. Preliminary findings indicate that curriculum that promotes inquiry cannot be efficient. The efficiency-effectiveness tension seems a primary reason that many students and teachers are found deficient at scientific reasoning skills.

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