Communicating Scientific Ideas: One Element of Physics Expertise

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Abstract. In this paper we present an alternative perspective to physics expertise research. Using Lave and Wenger's theoretical perspective of Legitimate Peripheral Participation [4] as a guide to understanding expertise development, we redefine expertise from the perspective of physicists. We analyze data from an ethnographic, qualitative study of a physics research group and draw data from multiple sources to triangulate a definition of expert. Results show that a very critical part of becoming a physics expert in this physics research group is communicating one's scientific ideas through writing. Students perceive scientific writing as an important aspect of participating in the research group and it is a significant discussion point in the research meetings. Thus, it appears that learning to write a scientific paper is a process congruent to developing physics expertise.

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INTRODUCTION

Literature on experts in physics has been situated in the cognitive literature to distinguish experts from novice physics problem solvers [1-3]. In this paper, we take a different approach to physics expertise, and examine how one becomes a physics expert. To answer this question, we take the socialization model described by Lave and Wenger [4], legitimate peripheral participation, which is a framework to interpret the process of becoming an expert within a group. Legitimate peripheral participation within a community of practice describes how a newcomer will change their participation in a community to learn to do what experts do in that community.

Previous studies that have researched the socialization process of graduate students into a science discipline have found that contributing to the scientific field formally through writing scientific papers and publishing in scientific journals is a large component of becoming a member of the community and establishing oneself within the community [5-6]. It is understood that publishing scientific journal articles in academia is an important part of one's career and has been used in factor analysis of career productivity and success in the discipline [6-7]. While publishing has been explicitly used as an indicator of expertise, this paper describes both the process of writing a scientific paper in a physics research group and how this process is associated with becoming a physics expert.

THEORETICAL FRAME

In describing the process of developing physics expertise, we take the perspective of the apprenticeship model of learning to explain the process of becoming a member of a community. Becoming a member of a community is a socialization process that involves learning about a group's culture, norms, expectations, and skills along with the values necessary to succeed in the community [8-10]. Lave and Wenger outline this process in their learning model of legitimate peripheral participation within a community of practice, in which learners or novices increasingly participate in legitimate social practices.

In a community of physicists, those who aspire to become experts in this community find that language, and more specifically written language, is necessary to communicate with and inform other physicists of the physics knowledge constructed [2-3]. To learn a language (including written language) is also to learn a culture, because culture and social interaction are the only contexts in which a language has meaning [5]. Therefore, learning to write within the physics community becomes a crucial part of the socialization process from novice to expert. In this paper we address how physicists socialize novices to contribute and communicate with the field by learning or participating in the process of writing scientific papers.

DATA AND PARTICIPANTS

This paper analyzes data as part of an ongoing ethnographic, qualitative study of a physics research group. Our study involves six months of participant field observation and video recordings of the physics group weekly research meetings. We also collected video and audio recorded interviews with each regular member of the research group concurrently and subsequently to the six-month data collection period.

Participants in this ethnographic case study [11] are located within the physics department of an R1 American university with a student enrollment of about 44,000. The participant group carries out research in theoretical and computational biophysics. Two university physics professors, Mathew and Prakul (all names are pseudonyms), lead the research team. Omar is an adjunct professor with the university who spends time doing research with the group. There are three graduate students, Udit, Hal, and Ike, and an undergraduate physics student, Louis.

The group meets once a week in meetings that last on average about five hours to present the theoretical and computation findings to the research supervisors, Mathew and Prakul. During the presentations, the group discusses and evaluates the progress of the project's findings and plans the next steps of that particular project. It is an assumption that a project and its results will be written up into a scientific paper. This is the evidenced by the fact that the words "project" and "paper" are used interchangeably through the research meeting conversations on each project. Most notably, what are presented at these meetings are often graphical and pictorial representations of the physical phenomena the group members are researching.

RESULTS AND DISCUSSION

A triangulation analysis [11] of the data sources reveal that this physics research group shares the perception that experts contribute new knowledge to the field and communicate by writing and publishing in scientific journals. We also show how this particular research group explicitly socializes its members to write scientific papers. Specifically, we show how the lead professor divides the process into three stages or levels of participation that are congruent with the progress of the graduate students becoming experts.

Contributing as a marker of expertise

This physics research group was very much consistent in their perception of what an expert physicist is. Professor and student interview responses to the questions about what makes a physics expert and what they hope to learn and achieve in their career were consistently related to contributing to the field and publishing research. The interview segment below shows what Mathew perceives as the attributes of expertise: knowing what questions to ask, knowing how to approach the questions, and contributing to the field.

> Mathew*: What makes somebody an expert is knowing what the important question is, and knowing how to approach those important questions. The other aspect is having contributed new knowledge to the field…*
> Interviewer: *Out of your group members, who would you consider an expert?*
> Mathew*: The ones you might expect. Besides myself, Professor Prakul. Dr. Omar has expertise in specific areas. Cause he has done all three of those things, his name is on a couple of papers.*
> Interviewer*: So would you consider being published a very important aspect of that?*
> Mathew*: That's the third part of it that you've contributed to the field…*

Mathew later went on to describe some of his graduate students as experts and defined them as such if they had these attributes but most importantly, the third attribute of contributing to published research.

Other members of the group share the perception that experts in physics are people who publish their work. Graduate student Ike solely defined physics experts as people who have published quality research in physics journals. Before he graduates, Udit hopes to make this time the most "prolific" of his graduate career. He claims that "at the end what counts is your publication, how many publications you have and how good the paper is." Therefore, graduate students in this group view publications as signs that their contributed research is accepted in the field.

Since communicating one's research through publishing and writing papers is a critical part of achieving expertise, the question remains of how one learns to write and publish in scientific journals. Other research groups have students research and write the papers with the guidance of their mentor [5]. This biophysics research groups takes a scaffold approach to the writing process.

Apprenticed to communicate in the field

In this research group, the mentors have adopted a specific process of socializing students to contribute to physics research papers. Interestingly, this process of writing scientific papers is interdependent on developing expertise. We will now outline the process

of contributing to scientific publications from Mathew's interview responses.

Mathew outlined how contributing to scientific papers in his group depended on the graduate students' progress. First, a beginning graduate student is not expected to write the paper but to contribute by doing the research. "They may just be doing a lot of the computer simulations and we will be saying 'we need the data point at 320° because that looks like where the peak of the heat capacity curve might be.'"

Later, as the students gets a feel for the topic, they may be instructed to write an outline for the paper where they should be deciding on what graphs and figures to include in the paper.

> Mathew*: A paper has to have a point, now how do you convey the point based upon your research? In other words, other physicists are going to be reading this paper, are they going to believe that you've proven your point… A good way to get them thinking about how to convey the logical argument that leads to the results, the point, is 'which graphs do you think that would be important?'*

The final step in the process is when the students are actually ready to be "thinking about the discussion and the conclusion section and where else it might lead to." Mathew points out that none of his current students are at this last point; instead they are all where they can make good suggestions about graphs and figures that should be in the paper.

Members assimilate the socialization process

Members of the research group have assimilated the three levels of participation in scientific papers. Many of the weekly meetings revolve around changes and edits that need to be made to each of the ongoing projects or papers. In the setting created in the meetings, any student can learn from another student's progress or questions. Students give suggestions about the kind of language to use when describing the graphical representation of the protein folding time, for example. More specifically, at one meeting, the mentor, Mathew, requested that Hal review the manuscript on florescent proteins and focus on the methods and results section to check if what is written was a good representation of what was done. Mathew's request for Hal's input on the manuscript is evidence that Mathew accepts and values Hal as a participant in the writing of the paper.

The process of contributing to a paper has also been established as a group norm that the students learn to adopt. In the interview with Louis, the undergraduate, he delineated where he saw himself in the process. The interviewer asked him about what he learned in the group and he said "research papers." The interviewer understood that Louis learned to write research papers but he rectified this and said:

> Louis*: I am not going to write the paper. I don't think- I think Professor Mathew has an idea to include my work in the paper but I don't think I would be writing word by word. My English sucks. He would ask me to write like an outline with the important things, but I wouldn't be writing out the whole thing.*

Louis identified his role in the writing process to be in the beginning stages. He was consistent with Mathew's expectations of a student just starting to do research.

Communicating with graphical representations

Mathew emphasized the second level of participation for students in the process of contributing to a paper. He gave specific examples of "outline the results section" by using graphs and figures to tell the story. Previous research [12] argues that figures and graphs are the language of physicists. This is consistent with the practices of this group, which spends significant amounts of time discussing graphical representations.

Learning to interpret figures and graphs and to use them to build a scientific argument becomes an important socialization task as the students evolve as physics experts. In one research meeting, Mathew and Prakul purposefully spent the entire meeting going over editor comments on Udit's manuscript. They discussed changes that needed to be made to the figures and if they needed specific graphs to convince the reader of the point they were trying to make. Activities such as addressing reviewer comments, which are often dealt with privately between authors and coauthors, now became a social activity for the entire group to learn from. The showcase of editor comments to a manuscript in the meetings not only helps the student on the project receive feedback from all members of the group, it exemplifies the expectations of a student at the second level of participation in the writing process, and the activity becomes a learning opportunity of the norm practice in the biophysics research field.

Apparent contradiction

We wish to direct the reader back to Mathew's interview comments on what defines an expert. He listed three attributes that make an expert: asking the important questions, knowing how to approach the important questions and contributing to the field in the form of publishing the work he has done. Following his definition of an expert, the interviewer asked him

who in his group he considered an expert. He started to list the expected professors, but he continued to label some of his students as experts.

> Mathew*: Udit has expertise in a very narrow aspect of the computational molecular biophysics. I say that because his name is on a published paper. Hal is getting awfully close to having expertise in molecular dynamics calculations… Ike is like Hal, he's getting very close to having expertise in a specific area.*

In the previous excerpt, Mathew characterized his graduate student Udit as an expert, because he has all three attributes and has coauthored a paper.

However, this contradicts Mathew's statement that none of his students are at the last level of participation: "thinking about the discussion and conclusion section and where else it might lead to." There seems to be an apparent contradiction between what makes an expert and consequently whom he considers an expert, and where in the writing process his students are.

We can make sense of this apparent contradiction by interpreting Mathew as discussing different levels of expertise dependent on specificity. In a previous study [13], we introduced a model of physics expertise, which depends on specificity. The model describes how one becomes a *specific physics expert* in a very narrow field of physics or even a specific topic within a field. In developing that specific expertise, one attains the *general physics expert* characteristics common among many fields of physics.

We interpret Mathew's distinction between Udit's expertise in a "narrow aspect of the computational molecular biophysics" and his participation in the writing process not being in the final stages as a distinction between Udit being a *specific physics expert* and yet not having attained *general physics expert* characteristics. Being a student does not exclude one from the label of an expert; it is one's expertise that is narrow and specific to the topic of the published paper. At the same time, being a student identifies a certain "incomplete" aspect of the trajectory toward expertise.

CONCLUSIONS

This study suggests that physicists in this research group are partially socialized into becoming an expert through the process of contributing to writing a scientific paper. In this biophysics research group, writing a scientific paper is not only associated with the socialization process into the community of practice in physics, learning to write in the community is a process that one is apprenticed into and a social process itself. All members of the group can participate in giving feedback about the manuscript and thereby learn the expected norms of the group.

In this group, students participate in the writing of a manuscript in different stages. Beginners conduct research and observe how the paper is written, which gives them a reference of how a scientific paper is written. Later, they contribute in the form of an outline and identifying what graphical representation and figures should be included. The last stage is when students are ready to give insight to the discussion and conclusion section in the paper, because they have the knowledge to direct their own research and evolve as a *general physics expert* [13].

The process of developing physics expertise is complex, yet we can study in detail the practices one physics research group and identify the smaller processes that graduate students experience. Observing one group limits the ability to generalize to physics at large, but it serves as a guide to identifying the common skills and communication norms of the field so that we can later teach those specific skills to graduate students aspiring to become physics experts.

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