Measurement uncertainty: a lever for the professional development of out-of-field physics teachers

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Abstract: This study examines the negotiation of epistemological approaches between out-of-field teachers (with training in biology) and in-field physics teachers as they engage in an argumentative activity on measurement uncertainty. The activity was designed along the lines of the Knowledge Integration theory so that the biology teachers' disciplinary knowledge can serve them in constructing knowledge in physics. We report on a case study that reveals the different epistemologies of the teachers and highlight the opportunity that argumentative activities, designed to bring forward participants' disciplinary backgrounds, hold for the professional development of out-of-field as well as in- field physics teachers.

1 Rationale & research questions

Teaching out-of-field (OOF) is a widespread phenomenon in middle school physics education. Teachers trained in biology are often assigned to teach physics. OOF teachers have low self-efficacy, which impairs students' achievements and leads to their distrust [1]. Professional Development (PD) programs ordinarily serve in-field (IF) physics teachers alongside OOF teachers, resulting in the discomfort of the later to voice their ideas, ask questions or seek support [2]. From the Knowledge Integration theory perspective [3], effective PD should draw on and refine participants' prior knowledge. In the context of OOF physics teachers, this translates to an 'interdisciplinary' approach that considers the disciplinary knowledge resources of biology teachers to design tasks where OOF teachers can rely on these disciplinary resources within the physics context. An illustrative example is to design physics activities that emphasize experimental research practices that are more prevalent in the biology instructional lab (such as controlling variables or determining measurement uncertainty [4]). Structuring argumentation in such PD activities can allow OOF and IF teachers to articulate their respective views, negotiate their ideas, and construct mutual knowledge. This study focuses on the dialogues that emerge between OOF and IF teachers in the context of an argumentative activity designed to develop a deeper understanding of measurement uncertainty. Specifically, it examines the negotiation of divergent epistemological approaches between OOF and IF teachers during the activity.

2 Methodology

Data consisted of recordings of teachers' discussions when engaged in an argumentative activity in the context of yearlong PD workshops (60h) accompanying the 'Gateway to Physics' program. In this program teachers experienced as learners inquiry-based modules intended for STEM middle-school students in excellence tracks. Later, as teachers, they reflected both on their experience as learners, as well as on their classroom experiences. The activity was designed to: 1) problematize and conceptualize key concepts involved in the measurement process (e.g., reading, measurand, measurement, measurement uncertainty) [5]; 2) apply these concepts to determine whether or not the falling time of an object depends on its mass.

The activity was designed along the lines of the Knowledge Integration theory [3] to induce the four learning stages: *elicitation* of prior knowledge, *adding* new ideas (presented by peers, artifacts or instructor), *developing criteria* to determine the explanatory power of ideas, and, ultimately, *sorting out* ideas to form explanations, as shown in Table 1.

Table 1: description of the materialization of the Knowledge Integration theory in sample tasks.

Description of the task (artifacts and instructions)	**Alignment with Knowledge Integration Theory**
Participants are asked to decide and justify whether two sets of measured falling times, whose average is the same, are equally good, or is one better than the other. The measured values were chosen to trigger the point-paradigm [6] - recognizing the average as the only descriptor of this quality while ignoring the spread.	***Elicitation*** of participants' prior knowledge concerning the quality of a set of measurements. ***Adding & developing criteria****:* Argumentation was structured via an organizing table; participants wrote their claims and justifications and argued towards agreement.
Participants are offered 2 methods for quantitatively estimating measurement uncertainty, and are asked to evaluate and discuss their advanteges/disadvanteges: 1. The range (max.-min.) of a set of measurements. 2. The average of the subtractions of each of the measurements from the average of the measurements.	***Adding*** scientifically accepted and non-accepted ideas. ***Developing criteria*** by discussing the advantages and disadvantages of methods for estimation of measurement uncertainty and ***sort out*** these ideas in a following class discussion, introducing a third method more compatible with that of the scientific community.

We collected data from 13 groups (N=43 teachers, both IF and OOF). The video-recordings of the discussions were transcribed. We report a case study of a group of three teachers: two IF teachers (male & female) and one OOF teacher (female). The data analysis was inspired by the boundary crossing theoretical framework [7], identifying discontinuities in interaction between the different teachers that reveal the epistemological boundaries between them.

3 Findings

The IF teachers expressed views closer to the point-paradigm described in the literature [6]. For example, after a single measurement of the falling-time of a paper cup, the teachers were asked: "*suppose you repeated the measurement. Do you think you would get the same time-reading*?" The IF teacher responded: *"If it's from the same height then yes… If we do exactly the same thing, in exactly the same way… we will expect to get the same results"*. On the contrary, the OOF teacher explained the limitations of the range method, expressing views closer to the scientific view of measurement uncertainty. The IF teachers dominated most of the discussion, and the voice of the OOF teacher was barely heard. However, when comparing the different methods for effective estimation of uncertainty, the IF teachers changed their attitude and listened cautiously to the OOF teacher's ideas. These findings indicate that the topic of measurement uncertainty is fruitful for enabling 'interdisciplinary' argumentation between physics teachers from different backgrounds. The activity, designed in accordance with the Knowledge Integration theory, revealed the epistemological boundaries between the teachers and promoted negotiation across them.

References

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