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High school physics teachers' professional noticing in the context of group-oriented learning analytics dashboards

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Abstract

The evolution of blended instructional environments requires teachers to extend professional noticing to learning analytics data presentations. This research is situated in the context of dashboards generated by a clustering algorithm that analyzed the performance of over 300 high school physics students on a diagnostic questionnaire and clustered them into characteristic performance profiles, which the algorithm then projected on specific student cohorts. Teacher noticing was elicited using semi-structured interviews centered on three dashboards presenting students' performance, and teachers were asked to characterize emerging problem-solving knowledge and suggest responses to identified issues. Analysis of interview data from a sample of 10 experienced physics teachers revealed that teacher noticing was sensitive to dashboard features. While teachers tended to focus on individual students during the characterization stage, they preferred to address groups or the whole class at the response stage and focused less on providing individual students with personalized support.

Keywords: blended instruction, dashboards, learning analytics, physics education, problem-solving, teacher noticing

INTRODUCTION

Over the past decades the traditional classroom teaching-learning space has expanded to include digital platforms such as learning management systems, intelligent tutoring systems and video conferencing platforms. These digital platforms support a variety of teaching interactions and produce innovative reports based on educational data mining (EDM) and learning analytics (LA), often in the form of visual dashboards (Lodge et al., 2020; McKnight et al., 2016; Pozdniakov et al., 2023; Romero & Ventura, 2013). Leading position papers highlight the benefits of blended instructional arenas, integrating digital tools to empower the teacher's ability to receive real-time information on students' learning as they engage in classroom tasks (OECD, 2023, pp. 22-26). Performing effectively in these evolving instructional spaces requires teachers to develop professional noticing–the knowledge and skill to attend to, interpret and act upon data generated in an arena combining face-to-face and digital interactions. Teachers' difficulties in noticing the diversity and nuance of student ideas in a classroom are well documented in the traditional, face to face setting (e.g., Sherin et al., 2011).

Blended settings involving multiple interfaces may exacerbate these difficulties (Campos et al., 2021). Teacher noticing during varied grain-size teacher-student interactions involves additional challenges, as teachers attend to different kinds of students' ideas and practices while interacting with individual students, mentoring small groups, or orchestrating whole-class discussions. Aiming to gain a better understanding of these difficulties, this study examined high school physics teachers' professional noticing of different grain-sizes, when faced with novel reports based on a group-oriented LA tool.

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Contribution to the literature

- This study extends the research on teacher noticing from the prevalent context of mathematics education to the context of problem-solving in high school physics.
- This study focuses on teacher noticing when viewing students' performance dashboards, rather than the more common artifacts of videos of student classroom behavior.
- This study contributes the facet of teacher noticing to the research literature on blended instruction and adds to former research on LA algorithms which present cluster performance profiles.
- The results reveal how teacher noticing is sensitive to dashboard features such as increasing grain size (students, groups, whole class), and to evaluation aspects (level of success on an item or the entire questionnaire and understanding knowledge components [KCs]).

THEORETICAL BACKGROUND

Teacher Knowledge and Teacher Noticing

One of the features that distinguishes expert teachers is their propensity for professional noticing, which includes three components: attention to salient features, interpretation and planning suitable action (Chan et al. 2021; Jacobs et al., 2010).

Expert science teachers are said to possess a complex knowledge structure consisting of pedagogical, science content and technological knowledge, as well as specialized combinations of these knowledge domains, such as pedagogical-content knowledge (Shulman, 1986, 1987) and technological-pedagogical-content knowledge (Mishra & Koehler, 2006). As they engage in each of the facets of the instructional operation, teachers draw on their knowledge and experience as resources to guide them in interpreting and making sense of the instructional situation and deciding how to proceed, either in-the-moment or for planning ahead (Campos et al., 2021; Schoenfeld, 1998).

Professional teacher noticing can be seen as strategic knowledge which falls in the domains of pedagogical-content-knowledge or technological-pedagogical-content-knowledge, as it involves using pedagogical knowledge, science content and/or technological knowledge to attend to students' performance, interpret it to detect learning patterns, and plan instructional action to respond to the revealed situation (Blömeke et al., 2015; Lee, 2018; Meschede et al., 2017; Wilson et al., 2019).

Effective teacher noticing is a crucial factor in the instructional process as it ensures timely attention to learning gaps and planning of remedial response to student needs, and it promotes simultaneous response to groups of students with common understanding profiles. Clearly, promoting informed teacher noticing in different situations is a valuable professional development goal. However, it is essential to point to several factors that impact our understanding of teacher noticing:

1. Teacher noticing is contextual: In addition to pedagogical, content and technological knowledge teachers possess, they tend to construct an image of their students' personal history and character traits as well as the particular instructional context in their schools. Teacher noticing may be affected by this "contextual knowledge", and teachers often attribute their portrayal of students' thinking to student characteristics and circumstances or school context (Evans et al., 2019; Kibert, 2016).
2. Teacher noticing takes place in a multiplicity of instructional settings. It commonly occurs in the moment, during real-time classroom instruction, laboratory activities, or while assessing student performance on assignments and tests (Luna et al., 2018). However, teacher noticing has been studied in additional contexts such as viewing video recordings of a lesson (Amador et al., 2021; Kosko et al., 2022; Luft et al., 2024; Sezen-Barrie & Kelly, 2017; Superfine & Bragelman, 2018; Weyers et al., 2023; Wulff et al., 2022; Zuo et al., 2024), viewing artifacts such as LA dashboards of student performance (Dickler, 2021; Xhakaj et al., 2016), and evaluation of instructional software (Smith et al., 2018; Yeo, 2023).
3. Teacher noticing is tacit: Expert science educators attend to salient classroom instructional features, interpret them, and decide on action plans implicitly, often without explicit, conscious deliberation (Sherin & Star, 2011; Steinwachs & Martens, 2025). Thus, debriefing expert science teachers about their teacher noticing is not straightforward.
4. Teacher noticing depends on teachers' trust, which varies across different interaction interfaces. Teachers who integrate digital platforms in their instruction and receive the dashboards need to be able to interpret the learning situation in their own class, attend to the achievement map in relation to the knowledge components (KCs) related to each question, interpret the learning gaps, and design informed remedial instruction for individual students, groups of students, or the whole class. This raises the issue of teachers' attitudes towards the LA

dashboards (Cojean et al., 2023). In particular, the decision on subsequent action paths, for which the teacher will be held accountable, requires an understanding of the LA algorithm's margins of error and trust in its judgement, while critically comparing the digitally generated learning landscape with the teacher's firsthand contextual knowledge.

5. Research demonstrates that effective noticing is difficult, and many teachers struggle to notice the diversity and nuance of student ideas in a classroom (e.g., Sherin et al., 2011). Machalow et al. (2020) claim that teachers do not tend to use professional noticing of children's mathematical thinking without focused education and support, and that curriculum programs should support teachers in developing professional skills for noticing mathematical thinking. Technology has been developed for scaffolding the teacher practice of responding to student ideas, thus enhancing teacher noticing (Bywater et al., 2019). This difficulty is even more likely to surface in less familiar situations such as viewing novel LA dashboards.

This study aims to examine high school physics teachers' professional noticing in relation to LA reports on their students' problem-solving performance. Problem-solving, a key component in the physics classroom, is at the center of these reports, and thus, they reflect desired learning goals.

Physics Problem-Solving: Learner Difficulties, Evaluation Criteria and Tools

Problem-solving forms the core of assessment in the physics class focusing on both the assessment of conceptual and procedural knowledge, as well as the student's approach to problem-solving (Yerushalmi & Eylon, 2015). Extensive physics education research has focused on characterizing conceptual problem-solving difficulties (e.g., Heron, 2018)–widespread naïve ideas in specific subjects, faulty procedural knowledge, and difficulties in organizing connections between concepts and principles, such as classifying problems by surface features (Chi et al., 1981). Research also characterizes differences between novices and experts in their approach to problem-solving which are manifested by experts spending more time on a qualitative analysis of the problem, planning a problem-solving strategy based on sub-tasks and engaging in reflection and monitoring along the solution path and adjusting it as required (Reif, 2008). These characteristics are useful in identifying expert-like approaches to problem-solving and applying them in rubrics assessing student problem-solving such as the Minnesota assessment of problem-solving rubric (Docktor et al., 2016, p. 5), based on the following criteria: useful description; a physics approach - selecting appropriate principles; specific application of physics knowledge; mathematical procedures; and logical reasoning. The suggested assessment rubric differentiates between the identification (retrieval) of appropriate principles and concepts (the "physics approach" criterion) and the actual application of those principles to the specific conditions in the problem.

The central role of problem-solving in physics instruction has promoted the development of digital systems coaching students in the process of solving physics problems, such as the Andes intelligent tutoring system (van Lehn et al., 2005) and Khanmigo, the Khan Academy AI-powered tutor (Khamari & Patel, 2024, p. 154). Such systems are based on analysis of learners' problem-solving performance and diagnosis of difficulties. The development of digital systems for diagnosing learner performance, detection of learning gaps and adaptation of the instructional depth and style to the unique needs of each student requires a systematic process of organizing and mapping content knowledge (Tomlinson, 2015). This knowledge organization can be achieved by mapping the entire "knowledge tree" (Novak & Cañas, 2008), or by cognitive task analysis related to particular problem-solving tasks (Koedinger et al., 2012; Larkin et al., 1980).

A different approach uses big-data based LA and EDM applied to the performance of large cohorts of students on a set of diagnostic assessment tasks. By applying cluster analysis algorithms to the data, the students are subdivided into groups with similar problem-solving profiles (Amershi & Conati, 2009). This clustering can be followed by a system of recommendations for each of the groups (Bienkowski et al., 2012). By comparing the cognitive task analysis to the problem-solving profiles that emerge from the clustering algorithm, it is possible to discover unexpected student difficulties.

Research Goals and Approach

We hypothesized that the challenges of teacher noticing in general will be expressed in unique ways in the less familiar digital environment with LA generated performance dashboards. Studying teachers' noticing of digitally created performance dashboards can shed light on teachers' attention foci under different dashboard presentations and on the relationship between output information formats and the awareness and reactions they trigger.

The primary goal of the research is to characterize teacher noticing–what performance profiles do teachers attend to in the dashboard data presentation? How do they interpret and plan instructional actions that relate to these profiles? The research approach was to explore this professional practice in the context of high school physics teachers viewing dashboards generated by a group-oriented LA tool. These dashboards present, in different ways, student performance on a questionnaire designed to assess conceptual understanding and problem-solving approaches in a specific physics domain. High school physics teachers' noticing, as they view different LA dashboards of student performance, will be elicited through prompts asking them to characterize the data and suggest instructional responses for their students. Here, "characterization" includes attending to salient information and interpreting it, while suggesting "response" means planning appropriate instructional actions. The analysis during the characterization and response stages will focus both on focal subjects of different grain size as well as on several evaluation aspects of students' problem-solving performance.

The study has the potential to expand the scope of published research on teacher noticing, which has predominantly focused on mathematics teaching in the classroom environment (Choy & Dindyal, 2022; Jacobs et al., 2010; van Es & Sherin, 2002), with few studies addressing science teachers (Luft et al., 2024) or physics teachers (Dickler, 2021). The findings can contribute to the design of teacher-facing dashboards that support teachers in planning and providing effective follow-up instruction to individual students, student groups, or the entire class (Mavroudi et al., 2018), as well as serving the design of professional development initiatives to empower teachers to take advantage of the digitally presented information.

METHODS

Data Collection Tools

The development of the data collection tools consisted of LA dashboards presenting student performance on a diagnostic questionnaire in electromagnetism, and semi-structured interviews for eliciting teacher noticing upon viewing different dashboards related to their students' performance. The design of the LA dashboards involved three aspects:

(a) a digital learning environment,

(b) a diagnostic questionnaire, and

(c) LA tools.

The Design of the LA Dashboards

The digital learning environment

The LA dashboards were generated from data collected in the personalized teaching and learning (PeTeL) digital learning environment (Yacobson & Alexandron, 2024). Based on the Moodle learning management system, PeTeL consists of several STEM subject tracks, each of which includes a repository of open educational resources, a learning management system offering teachers LA tools and a social network affording collaboration and communication among teachers. During the research period, which coincided with the COVID-19 pandemic, the physics track of PeTeL was adopted by over half of the state's national workforce of physics teachers.

The diagnostic questionnaire

The questionnaire focused on a specific physics topic–motion of charged particles in a magnetic field (see **Appendix A**). The questionnaire items were selected from the existing PeTeL item repository, with preference given to items that had gained popularity among teachers (judging by the number of download requests), thus ensuring relevance. Aiming to probe students' conceptual knowledge as well as their problem-solving approach, the selected questionnaire items focused on conceptual difficulties documented in the research literature (Li & Singh, 2016; Maloney et al., 2001), as well as an expert-like approach to problem-solving (Reif, 2008; Yerushalmi & Eylon, 2015). The diagnostic questionnaire complied with the 12th grade elective physics national curriculum. It consisted of 18 items (multiple choice or restricted open answer). Items 13-18 were synthesis problems set in a context-rich scenario (Heller et al., 1992). Items 1-12 were simpler, one step questions. Solving the synthesis problems required conceptual and procedural KCs (which were also required by the one step items), as well as an expert-like problem-solving approach. The questionnaire was accessed via the PeTeL platform and was planned to be completed in class within 60 minutes.

The underlying KCs required for solving the questionnaire items were identified by an expert solution and explicated using a q-matrix format (Barnes, 2005). The KCs were derived from a theoretical framework differentiating two types of KCs required in physics problem-solving (Docktor et al., 2016): specific content-related conceptual knowledge and generic KCs that reflect an expert problem-solving approach. The generic components reflect aspects of an expert-like problem-solving approach such as a qualitative description of the problem scenario using physics terminology and dividing the problem into sub-tasks.

Learning analytics tools

The questionnaire was accessed by several hundred students over a period of about 2 months in 2021. Following performance by approximately 300 students, cluster analysis was performed by the GrouPer LA algorithm (Feldman-Maggor et al., 2024; Nazaretsky et al., 2022) which collected students' performance data from the PeTeL platform, performed k-means cluster analysis (Li & Wu, 2012), and identified five student groups with similar strengths and difficulties related to the problem-solving, which were represented by a group-item matrix (**Figure 1**). The number of clusters was determined using the gap statistic method

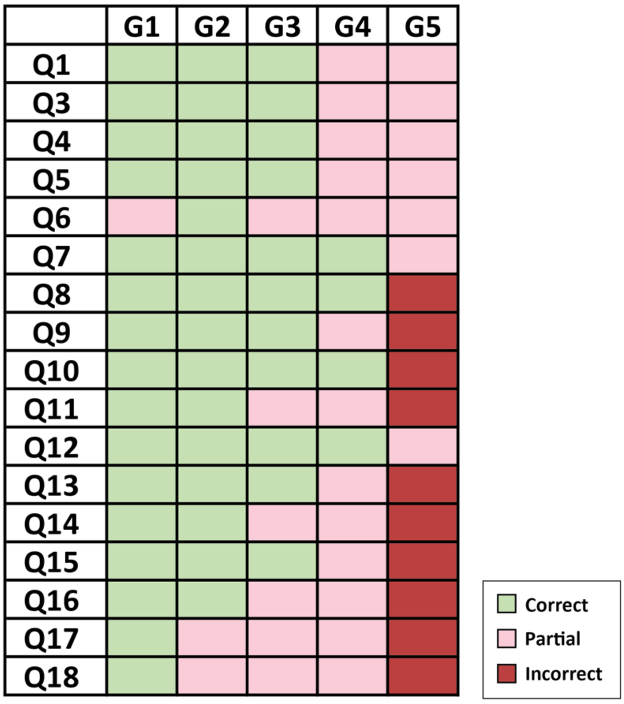

Figure 1. Group-item matrix (Source: Authors' own elaboration)

(Tibshirani et al., 2001), as described in detail by Din et al. (2023). The color assigned to an item within a group was based on the performance level of the group for the item (green = 80% succeeded; red= 80% failed; pink= other). Note that item 2 was omitted from the final report, owing to unsuitability.

Following the cluster analysis, physics education experts organized the KCs according to general knowledge structures (spatial perception, physics concepts and principles–retrieval or application, problem-solving approach, algebra) and identified strengths and difficulties in terms of the KCs for each of the five groups. **Table 1** presents the knowledge structures and the KCs that proved difficult for each of the automatically generated groups. For groups with many difficulties (G4), only the strengths are indicated.

The Semi-Structured Interviews

The goal of eliciting and analyzing expressions of teacher noticing regarding the information presented by the LA dashboards and its instructional implications was achieved by semi-structured interviews during which 3 different dashboards showing the teachers' own students' performance were presented. Upon viewing each dashboard, teachers were first asked to characterize their students' performance and later suggest an instructional response to the performance profiles.

To facilitate introspection, the interview was based on the comparison of artifacts, i.e., different student performance dashboards which were presented to the teachers in a fixed sequence. Henderson et al. (2007) and Yerushalmi et al. (2007) suggested that anchoring and comparing artifacts enables interviewees to externalize and label their conceptions. For each interview, a PowerPoint presentation was prepared containing the depiction of the questionnaire items, a table showing the KCs per questionnaire item and the three dashboards with lists of student names generated for the teacher's own class.

Dashboard A (**Figure 2**, the customary report generated by the PeTeL platform) presents individual student performance per item and the total grade. The title rows represent the questionnaire items in sequence (q1, q3, etc.) and the total points allocated to each item.

Table 1. Mapping knowledge components to groups and questionnaire items

Group	Typical difficulties (-)/strengths (+) in knowledge components	Related items	Knowledge structures
G1	(-) Vector representation in a 3D diagram	6	Spatial perception
	(-) Identifying the direction of the magnetic field created by a magnet	6	
G2	(-) Expressing the period of a uniform circular motion as circumference divided by the speed	17	Application of physics concepts & principles, problem-solving design
	(-) Expressing the length of a circular arc as related to the central angle which it spans	18	
G3	(-) As in G1 & G2	6, 17, 18	
	(-) Identifying the direction of the force acting on an object in uniform circular motion	11, 14	
	(-) Translating the problem description to physical entities	14, 16	
G4	(+) Knowing the Lorenz force formula	7	Retrieval of physics concepts & principles, algebra
	(+) Knowing the formula for the radius of the circular motion of a charged particle in a magnetic field	8	
	(+) Identifying the ratio between parameters in an algebraic expression	10	
G5	(-) Difficulties in all knowledge components	All	

ID	Grade	Q. 1 [3.4]	Q. 3 [3.4]	Q. 4 [13.8]	Q. 5 [10.3]	Q. 6 [3.4]	Q. 7 [3.4]	Q. 8 [3.4]	Q. 9 [3.4]	Q. 10 [3.4]	Q. 11 [3.4]	Q. 12 [3.4]	Q. 13 [13.8]	Q. 14 [13.8]	Q. 15 [3.4]
A	100	3.4	3.4	13.8	10.3	3.4	3.4	3.4	3.4	3.4	3.4	3.4	13.8	13.8	3.4
B	39	0	0	0	3.4	0	3.4	3.4	3.4	3.4	3.4	0	13.8	0	3.4
C	76	3.4	3.4	13.8	10.3	3.4	3.4	3.4	3.4	3.4	3.4	3.4	0	13.8	3.4
D	78	3.4	1.7	13.8	10.3	3.4	3.4	3.4	3.4	3.4	0	3.4	13.8	0	3.4
E	91	3.4	1.7	13.8	10.3	3.4	3.4	3.4	3.4	3.4	3.4	3.4	13.8	13.8	3.4
F	93	3.4	3.4	13.8	10.3	3.4	3.4	3.4	3.4	3.4	3.4	3.4	13.8	13.8	3.4
G	52	0	0	3.4	3.4	0	3.4	3.4	3.4	3.4	3.4	3.4	6.9	13.8	0
H	76	0	0	13.8	3.4	0	3.4	3.4	3.4	3.4	3.4	3.4	13.8	13.8	3.4
I	100	3.4	3.4	13.8	10.3	3.4	3.4	3.4	3.4	3.4	3.4	3.4	13.8	13.8	3.4
J	78	3.4	3.4	10.3	10.3	0	3.4	3.4	3.4	3.4	3.4	3.4	13.8	6.9	3.4
K	47	0	1.7	3.4	10.3	3.4	3.4	3.4	3.4	0	0	0	6.9	0	3.4
L	39	3.4	1.7	3.4	3.4	3.4	3.4	3.4	0	0	3.4	0	6.9	0	3.4
M	95	3.4	1.7	13.8	10.3	0	3.4	3.4	3.4	3.4	3.4	3.4	13.8	13.8	3.4
N	99	3.4	3.4	13.8	10.3	3.4	3.4	3.4	3.4	3.4	3.4	3.4	13.8	13.8	3.4
O	88	3.4	1.7	13.8	10.3	0	3.4	3.4	3.4	3.4	3.4	3.4	13.8	13.8	0
P	78	3.4	3.4	6.9	3.4	0	3.4	3.4	3.4	3.4	3.4	3.4	13.8	13.8	0
Q	85	3.4	3.4	10.3	10.3	0	3.4	3.4	3.4	3.4	3.4	3.4	13.8	6.9	3.4

Correct Partial Incorrect

Figure 2. Dashboard A: Individual student performance and grades (Source: Authors' own elaboration)

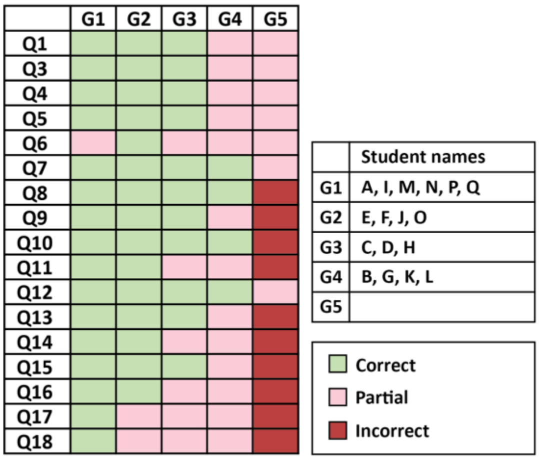

Figure 3. Dashboard B: Group performance + student names (Source: Authors' own elaboration)

Each row represents the points per item for a single student in the class. The matrix cells are green for correct answers, pink for partially correct and red for incorrect answers. A quick glance at the colored cells can detect individual students' performance, the difficulty of particular items and a general picture of the class performance.

Dashboard B (**Figure 3**) consisted of a 6-column matrix presenting the total population clustering and a table identifying the students in each cluster for the given class. To prevent data overload, the teachers were not shown the average success rate per item in each cluster nor any other quantitative information. Interviewees were told that the match between the performance of their own students assigned to one of the clusters was approximate and could be at different levels for several items.

Dashboard C (**Figure 4**) consisted of the same cluster matrix as dashboard B, along with a table containing semantic information describing the strengths or difficulties of each group of named students in terms of the KCs.

The first section of the interview introduced the researcher, explained the interview's goals and procedure, and requested informed consent for participation and recording. This was followed by a request for background information about the interviewee's school and teaching experience, the stage in the instructional sequence that the questionnaire was performed and the extent he/she used the PeTeL platform. The interview continued with a presentation of the questionnaire items intended to refresh the teachers' memories and enable consultation. Each of the following 3 sections was dedicated to a different dashboard and included several identical core questions, thus enabling comparison between teacher viewpoints regarding the information and efficacy of each dashboard. After each

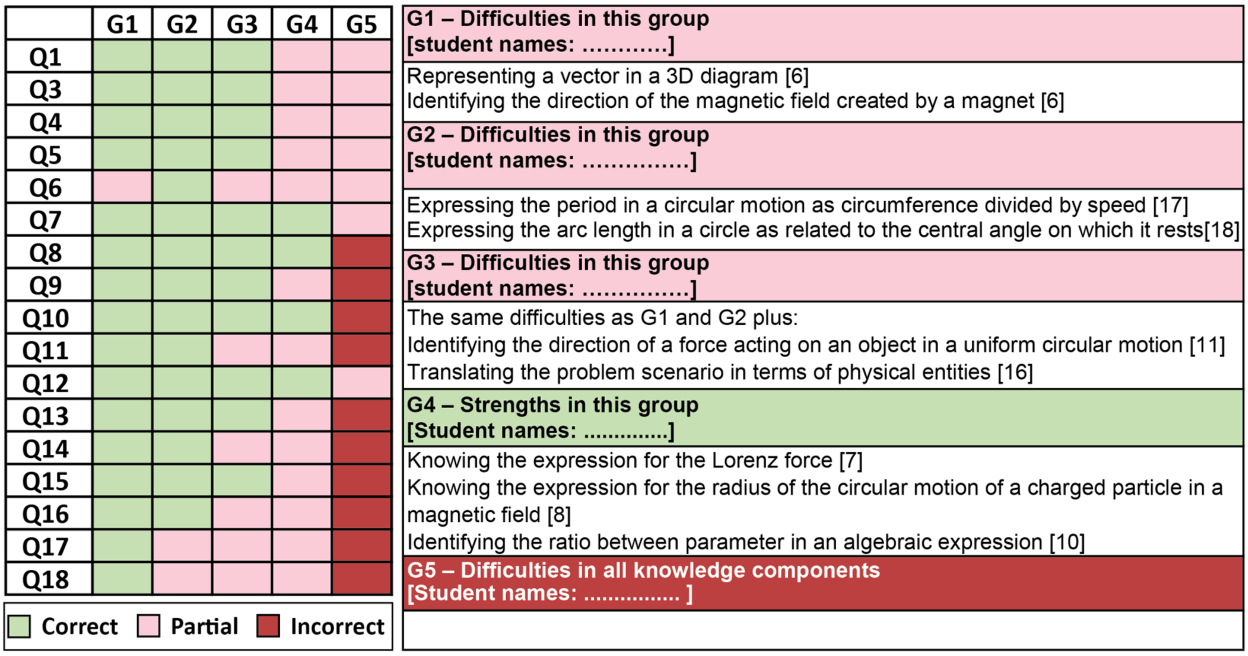

Figure 4. Dashboard C: Group performance + student names + group related knowledge components (Source: Authors' own elaboration)

Table 2. Categories and values for teacher interview analysis

Teacher-noticing component	Teacher's focal subjects for the dashboard	Evaluation aspects–Type of diagnostic information the teacher refers to
Characterization: attending & interpreting	Individual student(s)	Success in questionnaire items
Response: planning action	Group Whole class	Success in entire questionnaire Understanding knowledge components

dashboard was presented and explained the teachers were asked:

- What does the dashboard teach you about your students' performance in this activity (beyond the information in the previous dashboards)?
- How does the information in this dashboard match your perception of the class?
- What would you consider doing with the students in view of lessons learnt from the dashboard?

The final section included additional questions aimed at generating a broad, comparative view of the three dashboards.

Although the stepwise presentation of the dashboards may have driven the teacher-noticing trend, it had the advantage of reducing information overload by starting with the more familiar PeTeL dashboard, continuing with the new group-item presentation, and finally adding semantic information to the group-item matrix.

Data Collection Procedure

Ten of the 34 teachers whose students had completed the questionnaire were interviewed. This was a purposive sample of experienced physics teachers, all of whom were familiar with the PeTeL learning platform. Teacher background information indicates that the sample members had considerable teaching experience (3-30 years), with a median of 20 years. They were all affiliated with a national network of professional learning communities for physics teachers (Levy et al., 2025), either as teacher leaders (N = 5) or as participants in the learning communities (N = 5). A total of 165 12th grade physics students from high schools with varied socio-economic levels completed the questionnaire in the sample teachers' classes, representing an average 70% participation level.

The 30-45-minute interviews were conducted from March to May 2021. The interviews were conducted online, recorded (with the interviewees' consent) and transcribed.

Research Questions and Data Analysis

Two research questions (RQ) operationalize the research goals in terms of the collected data:

RQ1. What focal subjects emerged in verbalized teacher noticing related to the different dashboards during the characterization stage and the response stage?

RQ2. What evaluation aspects emerged in verbalized teacher noticing related to the different dashboards during the characterization and response stages?

The analysis of the verbal data combined qualitative and quantitative methods, and included selecting relevant analysis units, developing a coding category scheme, seeking patterns and interpretation (Chi, 1997). The categories were refined and updated through a process of spiral re-analysis. The coding was retested several times, leading to revised definitions and unification of initial codes. Some of the categories were defined top-down, reflecting the aspects addressed by the research, such as referring to an individual student, a group of students, or the whole class. Some of the categories emerged bottom-up from the data, such as differentiating between evaluating success in questionnaire items vs. success in the entire questionnaire. Agreement regarding the statement coding was achieved by the following procedure: A sample of randomly selected statements (~20%) were analyzed separately by two members of the research team and then disagreements about the statement coding and categorization were discussed with a third researcher, until a fully agreed coding method was reached. Ongoing discussions were held during the analysis of the remaining data to resolve disagreement regarding specific categorizations.

Table 2 presents the categories and values used to analyze the interviewed teachers' statements. The categories were selected to address the RQs concerning teacher noticing of the dashboards and how verbalized teacher noticing can be analyzed to characterize instructional situations and identify responses to emerging needs. The foci of teacher references to subjects are organized according to "grain size"–starting with individual students, followed by student groups and culminating with the whole class. The evaluation aspects were level of success related to questionnaire items, level of success related to the entire questionnaire and level of understanding related to KCs.

RESULTS

The findings are organized according to the two RQs and provide both quantitative and qualitative analyses of teachers' statements related to each dashboard, focusing on the characterization and response stages.

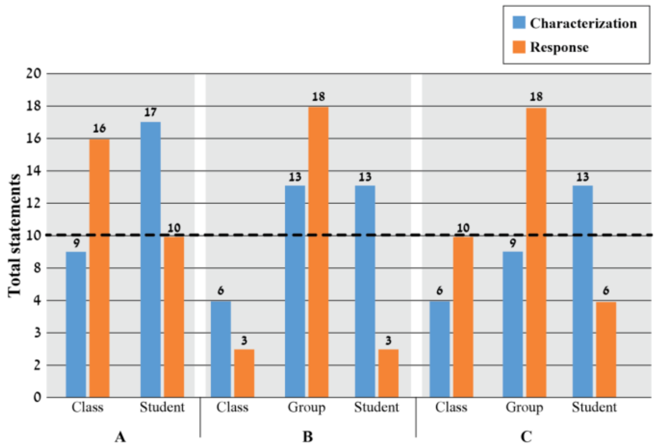

Figure 5. Distribution of focal subjects' statements for each dashboard during the characterization and response stages (the dashed line at N = 10 indicates reference frequency of one statement per teacher) (Source: Authors' own elaboration)

RQ1. Focal Subjects that Emerged from Teachers' Verbalized Noticing Related to the Different Dashboards During the Characterization and Response Stages

Teacher statements as they viewed the three dashboards were analyzed to identify instances of teachers noticing related to focal subjects of increasing grain size: individual students, student groups, and the whole class. **Figure 5** presents the frequency of teacher statements related to each focal subject in each dashboard during the characterization and response stages (blue and orange columns, respectively). We used one statement per teacher as a reference value for identifying prominent focal subjects (indicated by a dashed line at N = 10 in **Figure 5**).

During the characterization stage, the customary PeTeL dashboard A, drove teachers to focus primarily on individual student grades (two-thirds of statements, shown in blue). The remaining one-third of statements addressed the whole class.

Customarily, teachers tended to check the dashboard to see who had completed the assignment and whether the grades indicated a need to demonstrate the solution to the class or to speak with particular students, e.g., #8:

> "I look at the grades, if most obtained around 85, I just continue with the instruction. If I see low grades, I identify the relevant questions and students. If there are many, I solve the problem in class. If there are few, I catch the students in the break time."

A prominent focus on responses directed at the whole class was expressed in over half of the statements. #8:

> "First of all, I would present to the whole class the 2-3 questions that were problematic for most of the students. Even the good ones need to hear this once more", or #1: "I like to show the class the pie chart (without names), and this is reassuring for those who succeeded and motivating for those who require more effort."

Upon viewing group-oriented dashboard B, where groups first appeared, nearly half of the statements in the characterization stage expressed an equal focus on both group and individual student performance. For example, teachers discussed the performance of the class in terms of groups. #*9:*

> "I see there is a more or less equal division in the first 3 groups. That's more or less a third of the students in the high group, a third in the 2nd and a third in the 3rd. And I am pleased to see that none of the students are in G5, and only one in G4. That really agrees with my knowledge of the students."

On the other hand, observing small groups of students drove teachers to focus on individual students within the group context–comparing and checking the fit between the named students and their assigned group. #7:

> "Yes, these are two very good students. I see they sort of 'went off track' in this content and need to be brought back on track. I really received an excellent class mapping here, and this provides me with many more options. This Friday I have set a tutoring session, I would never have thought that I needed to invite S12, S6 and S4 to the tutoring session. But now I see that the situation is not too good with this topic. This gives me a better estimate who is struggling with this topic."

When viewing dashboard B, a prominent focus on responses directed at groups (which were distinguished by their performance on specific items) was expressed in 18 of the 24 statements.

Viewing dashboard C, which presented groups along with related semantic information, triggered a prominent performance characterization focusing on individual students' (almost half the statements) and a smaller focus on groups (about a third of the statements). This contrasts with the expectation that teacher noticing would align with the focus of dashboard C on group-level characterization. A possible explanation for this is the phrasing of the interview question, which required teachers to relate to the information each dashboard revealed beyond what was included in the previously viewed dashboard. Teachers maintained the same high level of response to groups, similar to dashboard B. #4:

> "This makes it really easy to create revision groups. …you can even give a student from G1 the task of explaining some topic to a student in G4. You can set the stronger students a more

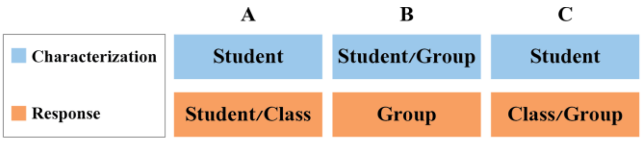

Figure 6. Prominent focal subjects during characterization and response stages for each dashboard (10 or more statements) (Source: Authors' own elaboration)

> complicated assignment while you sit with a small group of students dealing with their specific difficulties. This dashboard indicates the difficulties of each group, which only requires me as the teacher to address the difficulty and deal with it."

Figure 6 presents the prominent focal subjects per dashboard (statement frequencies ≥ 10) for the characterization and response stages. Summarizing across all dashboards, we find that while the teachers tended to focus on individual students during the characterization stage, attending to and interpreting learning issues (over half the statements), at the response stage they preferred to address groups, or to a lesser degree, the whole class (36 and 25 of 80 statements, respectively), and focused far less on providing personalized support to individual students. In particular, transitions of focal subjects in teacher noticing were observed for each dashboard:

- Dashboard A: From mainly individual student–focused characterization to mainly class-focused responses
- Dashboard B: From an equal focus on groups or individual students during characterization to mainly group-focused responses
- Dashboard C: From mainly individual student– or group-focused characterization to mainly group- or class-focused responses.

The challenge may lie in translating the personal acquaintance with students into personalized instructional strategies and treatment, due to constraints on time and attention resources. Another possible explanation is that designing responses for groups of named students defined in dashboards B or C was perceived as responding to the individual students within the small groups who share common performance patterns.

RQ2. Evaluation Aspects that Emerged from Teacher Noticing Related to the Different Dashboards in the Characterization and Response Stages

Teacher statements as they viewed the three dashboards were analyzed to identify instances of teacher noticing related to success on questionnaire items, overall questionnaire success, and understanding of KCs. **Figure 7** presents the frequency of teacher statements related to each evaluation aspect in each

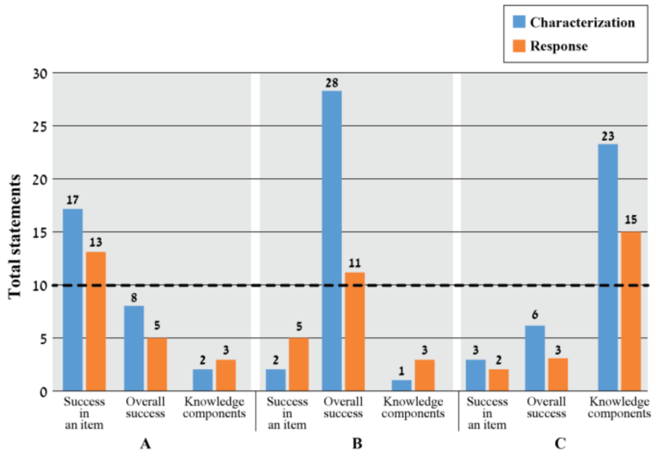

Figure 7. Distribution of evaluation aspects' statements for each dashboard during the characterization and response stages (the dashed line at N = 10 indicates reference frequency of one statement per teacher) (Source: Authors' own elaboration)

dashboard during the characterization and response stages (blue and orange columns, respectively). We used one statement per teacher as a reference value for identifying prominent evaluation aspects (indicated by a dashed line at N = 10 in **Figure 7**).

In the characterization stage, dashboard A triggered mainly evaluation of success in specific items, as expressed in about two-thirds of the statements, which is clearly visible from the display. Dashboard B predominantly triggered evaluation of success for the entire questionnaire, possibly because the group order was interpreted as a "league table". Dashboard C mainly triggered statements evaluating understanding of KCs (23 out of 32). It appears that the exposure to KCs in dashboard C was taken up directly, without requiring any additional prompting. All the teachers (except #7) referred to KCs in dashboard C, while only two referred to them in dashboards A or B. #1:

> "… since they know the formula for the force, they know the formula for the radius of the circular motion." And #6: "… then one knows how to work with the Lorenz force and selects the formula correctly but fails to find the correct connection with the radius."

In the response stage, the total number of statements related to evaluation aspects was similar for the three dashboards (21, 19, and 20), but the prominent aspect varied depending on the specific information each dashboard presented. Dashboard A, which presented individual student success for each questionnaire item, elicited mainly responses related to success in questionnaire items, in over half the statements. In dashboard B, responses focused on the entire questionnaire were most prominent (in over half the statements), as it was perceived to present the groups in order of overall success. For example, #4:

	A	B	C
Characterization	Success in item	Overall success	Knowledge components
Response	Success in item	Overall success	Knowledge components

Figure 8. Prominent evaluation aspects during the characterization and response stages for each dashboard (10 or more statements) (Source: Authors' own elaboration)

> "If I decide to give an extra lesson on this topic, I may release some of the students and work with just a small group. G1 and G2 and even G3 are in reasonable shape, so I can release them to perform an independent task, whereas G4 and G5 require more specific maintenance."

Responses focusing on group-related understanding of KCs were most prominent for dashboard C (15 of 20 statements), which related strengths and difficulties in KCs to each group. Almost all the teachers suggested responses related to KCs in dashboard C, while few referred to them in dashboards A and B.

Several transitions in teacher noticing related to evaluation aspects between the stages are noted. Across all dashboards the prominent evaluation aspects remained the same for the characterization and response stages (**Figure 8**). However, the total number of suggestions decreased (A: 27 to 21; B: 31 to 19; C: 32 to 20). This decrease was particularly noticeable for dashboard B, with a sharp drop in the evaluation aspect of success on the entire questionnaire (28 to 11). From the perspective of teacher noticing, the findings indicate only a partial ability to suggest remedial action paths for the instructional issues that were detected and interpreted. Dashboard B mapped the teacher's class to groups with specific performance profiles, with problematic items for each group indicated by pink or red squares in the matrix. This display did not generate adequate treatment strategies for improving students' overall performance. Instead, teachers tended to attribute student success to situational constraints explaining why students did or did not fit the groups to which they were assigned. A more encouraging picture is presented by dashboard C, which triggered attention to and interpretation of problems related to KCs (23 statements) and generated a reasonable number (15 statements) of specific suggestions for focused remedial instruction related to the KCs.

Dashboard preference

The interviewed teachers were asked which of the three dashboards they would prefer to receive soon after the questionnaire was completed and to refer to its relative advantages. Analysis of the teachers' responses yielded the following findings (note that some teachers named more than one favorite dashboard): Familiar dashboard A and inclusive dashboard C were the favorites (votes = 6 and 7, respectively). For example, #4:

> "A is immediate, visual and gives the general class status. I am used to it in PeTeL; C helps me focus on the topics to review in the next lesson, plus a broad view of the class, including the students who are totally off-track. Saves me checking every student in dashboard A. All I need to do is to divide them into the groups and deal with the required issues."

Dashboard B was also appreciated (votes=3). As #7 noted:

> "Let's say that when you showed me dashboard B, I said to myself: WOW, that's a report I would like to receive."

Since dashboard C contained the information presented in B, plus semantic information about KCs, its preference over dashboard B is to be expected.

Teacher noticing: Sense-making, insights and interpretation of dashboard information

Teacher noticing manifested itself in attending to performance information and interpreting it based on their "contextual knowledge" (acquaintance with the students and school set-up), without necessarily expressing a related action plan.

- Teachers provided non-knowledge-related explanations for students' performance, such as their personal traits (e.g., #6: "*He is a very wise and systematic student, but very anxious about making a mistake*"; #3: "*I have a girl in G4 who gives up after one second*"); general mood (e.g., #6: "*These students may have just decided to click on something and get it submitted*"); and conflicting commitments or the time of day the activity was performed.
- Teachers related performance to learning background (e.g., #2: "*This may be related to when the students answered the questionnaire. I believe RN and RM did it just before our exam, after they had finished going over all the material*"; #9: "*Maybe it was too early to let them do the questionnaire before we had sufficient practice*").
- Teachers referred to possible unauthorized student collaboration with others (e.g., #3: "*I gave this as a homework assignment. They did it at home with open material. There is also a possibility of using a 'phone buddy'*").
- Teachers referred to problems with the questionnaire items (e.g., #5 and #6: "*If he got it wrong in one of the items, then the error might be carried over to the next item*"; #2: "*The item states that the deflection was upwards, but the diagram is not very*

clear…it looks like it's to the left, not upwards") or with the digital platform (e.g., #10: "*Many times things get messed up when you enter parameters. KS is really an excellent student, and she is in G3. Possibly something technical went wrong*").

- Teachers mentioned the benefits of large-scale performance analysis reports: Indication of a problematic item formulation (e.g., #10: "*If an item was performed by many students and the success rate was very low, I would like to receive this information in the PeTeL platform. It indicates something may be faulty, and I should check it before giving it to students*"); and a self-reflection indication (e.g., #3: "*If you ask me how to use dashboard C then as a teacher, I can judge what I did well and what I did not do well*").

DISCUSSION AND CONCLUSIONS

The presented study aimed to examine teacher noticing in the contemporary blended instructional arena, where teachers receive digital, LA-generated dashboard information. Such dashboards facilitate the detection of hidden knowledge aspects and their explicit manifestation (e.g., visual clustering into groups with common performance profiles and semantic characterization of those profiles).

The research was motivated by the tension between two expectations: On the one hand, teacher noticing is already known to be challenging in traditional face-to-face classroom instruction (e.g., Sherin et al., 2011). Indeed, proficient teacher noticing is the hallmark of expert teachers, distinguished by their ability to handle the flow of rich, multifaceted classroom information, attend to knowledge fostering aspects, interpret the relevant information, and implement actions based on their integrated knowledge consisting of local context knowledge of the students and school setting as well as more specific pedagogical content knowledge (van Es, 2011). Since instructional decisions are anchored in the teacher's history, which serves to interpret new information (Karsenty et al., 2023; Schoenfeld, 1998), it is expected that less skilled teachers receiving unfamiliar information from digital sources may fail to notice its significance and ignore it. This is particularly true for teachers experiencing this information format for the first time, without appropriate professional development and training.

On the other hand, one may expect that explicit manifestation of hidden aspects will facilitate teachers' ability to provide appropriate instructional responses. This expectation is supported by recent studies. Feldman-Maggor et al. (2024) examined clustering explainability and teacher acceptance of group-oriented LA dashboards and concluded that teachers found the explanations insightful and largely comprehensible.

This tension motivated our investigation into what teachers actually focus on when faced with different LA-generated dashboards and what action plans they propose. Our research showed that teachers' responses ranged between enthusiastic adoption and willingness to implement the digital information, and reluctance to deal with this information format. The emerging picture appears to be more complex. Teacher noticing benefited from both the focal subjects and the evaluation aspects highlighted by the dashboards. Our evidence indicates that adding the semantic layer in dashboard C was considered highly useful by the teachers and directed their attention to specific KCs, which focused their action planning accordingly. Teachers also suggested ways to integrate their contextual knowledge with the information provided by the digital system. However, while the LA tool (GrouPer) was intended to help teachers promote group-level personalization, teachers' responses partially reverted to the customary, more manageable class size.

Two aspects related to the scale of the current research may limit its generalizability: the small research sample and the restricted physics content area. The semi-structured interview research was conducted with a small purposive sample of physics teachers (N = 10) experienced in using the digital learning environment. Due to the small sample size, the data analysis did not enable differentiation between teacher response profiles. Further research with a larger, more representative sample could reveal different teacher noticing profiles and facilitate customized professional development.

While the diagnostic questionnaire covered a limited physics content area, this limitation may be mitigated by the large number of varied items (one-step and synthesis problems) that covered multiple aspects of the content. Further research would benefit from diagnostic instruments dealing with other content chapters, as well as from using open-ended questions that would more precisely reveal students' knowledge and problem-solving skills.

The findings are particularly significant in the current era of integration of generative AI (GenAI) into the K-12 educational scene. With GenAI's capacity for providing detailed diagnostic information not only for closed-ended, auto-graded assessment items, but also for analyzing students' solution paths on open-ended items (Owan et al., 2023; Wan & Chen, 2024), the issue of information overload for teachers becomes critical. As teachers face a flood of finer-grained evaluation aspects embedded in students' problem-solving processes, it becomes highly important to help them focus on the aspects that promote learning (Blonder et al., 2024).

The call to provide personalized learning in the education system (e.g., Zhang et al., 2020) faces teachers of large classes with the challenging task of catering to diverse learning needs of many students simultaneously. Creating several student groups with similar instructional needs is one way to provide adapted instruction while avoiding student isolation and maintaining the pivotal role of the classroom teacher. LA tools use powerful statistical algorithms to analyze large-scale data on student performance on diagnostic questionnaires. These tools can generate knowledge-related group profiles that allow teachers a feasible way to adapt instruction to learners' profiles, even though they cannot attend to each individual student.

However, two requirements are necessary to ensure effective teacher noticing when engaging with the resulting LA dashboards: first, the diagnostic questionnaire must be designed so that success on item sets corresponds to identifiable learning goals; second, the emergent groups must be interpreted in terms of physics knowledge to support teachers' characterization of, and responses to, the emergent learning profiles. In the current study, these functions were performed by expert physics educators who were involved in the design of the diagnostic questionnaire and in the explication of the knowledge and skills related to the different groups. Their contribution to explaining the automatic clustering was acknowledged by the participating teachers. Recent advances in large language models and machine learning (Chen & Wan, 2025; Klebanov & Madnani, 2020; Zai, 2021) raise expectations for improved abilities of digital instruments to perform the semantic analysis on the questions and produce the semantic differentials for the different groups.

Teachers' ease of use of LA-generated dashboards depends on intelligent, human-facing design. The challenge lies in managing the tension between imparting rich information while preventing overload. This often necessitates a compromise between the specificity of group definitions and the number of groups. Teachers' decision making requires support from dashboard design with high usability features (Luo, 2020). LA dashboards should provide meaningful actionable recommendations (Matcha et al., 2019), which will affect the level of personalized, student-adapted, instruction that is enabled.

Effective teacher noticing is difficult to achieve, particularly in less familiar environments such as LA dashboards. Promoting sensitive teacher noticing requires targeted professional development initiatives that offer repeated opportunities for teachers to view, interpret, and discuss LA dashboards presenting grouping and semantic information about their students across various content areas. Artifact-based, semi-structured group activities discussing questions like "What do you see here? Does it fit your expectations?" may help activate explicit teacher noticing. Research on teacher noticing is also likely to benefit from advances in AI applications. For example, Wulff et al. (2022) reported that automated machine learning clustering tools were able to perform qualitative and quantitative analysis of interviewee statements to detect facets of teacher noticing.

Harnessing LA to the instructional scene has the potential to empower teachers by providing detailed, up-to-date information about student understanding, but it also risks overwhelming them with data overload. This tension drives the ongoing effort to design effective LA dashboards that provide actionable information and to plan appropriate professional development to scaffold teachers' ability to manage excessive information, while maintaining their central role.

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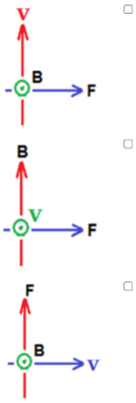
APPENDIX A: THE DIAGNOSTIC QUESTIONNAIRE

Questions

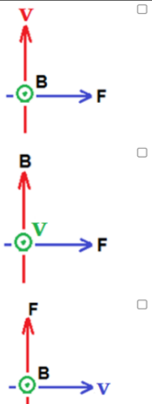
Q1

Which diagram/s show/s the direction of force on a positive particle moving in a magnetic field? Select one or more of the options.



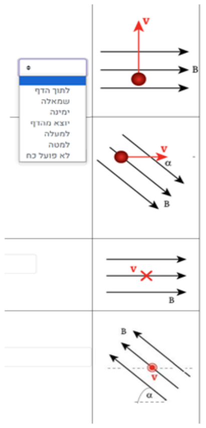
Q3

Which diagram/s show/s the direction of force on a negative particle moving in a magnetic field? Select one or more of the options.



Q4

A positive charge moving with velocity v enters into an area of a magnetic field. In some of the diagrams the particle enters at an angle of 30o. Select the direction of the magnetic force for each case.



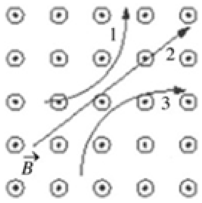
Q5

Three particles enter an area with a uniform magnetic field directed out of the page plane, as shown in the diagram. What is the sign of the charge of each of the particles?

The charge of particle 1 is … neg/pos/neutral

The charge of particle 2 is… neg/pos/neutral

The charge of particle 3 is… neg/pos/neutral

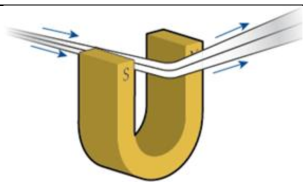


Q6

The diagram presents a beam of charged particles (all with the same sign) entering a magnetic field. As a results the beam deflects upwards relative to its original direction of motion. The charge of the particle beam entering the magnetic field is

Select a single answer

Positive/negative/unknowable.



Q7

Select the formula that correctly describes the force acting on a charged particle in a magnetic field.

Select a single answer:

- $F = qvBsin(\alpha)$ ○
- $F = qv^2Bsin(\alpha)$ ○
- $F = qvB$ ○
- $F = qvBsin^2(\alpha)$ ○

Q8

A particle with charge q moves along a circular path under the influence of a magnetic field B. The plane of the circle is perpendicular to the magnetic field lines, and the speed of the particle is v. The mathematical expression for the radius of the circular motion of the particle is given in the formula. Select a single option.

- $R = \frac{mv}{qB}$ ○
- $R = \frac{mv^2}{qB}$ ○
- $R = \frac{qB}{mv}$ ○
- $R = \frac{mv^2}{2qB}$ ○

Q9

A particle with charge q moves along a circular path under the influence of a magnetic field B. The plane of the circle is perpendicular to the magnetic field lines, and the speed of the particle is v. The mathematical expression for the period of the circular motion of the particle is given in the formula. Select a single option.

- $T = 2\pi\sqrt{\frac{m}{qB}}$ ○
- $T = 2\pi\frac{mv^2}{qB}$ ○
- $T = 2\pi\frac{m}{qB}$ ○
- $T = 2\pi\frac{mv}{qB}$ ○

Q10

It is known that an electron and a proton have equal charge, but the electron's charge is negative and the proton's charge is positive. It is also known that the mass of the proton is larger than the mass of the electron. An electron and a proton moving at the same speed enter into an area with a magnetic field at a direction perpendicular to the magnetic field.

Select one of the following options

a. The radius of the electron's circle will be smaller than the radius of the proton's circle.

b. The radius of the electron's circle will be equal to the radius of the proton's circle.

c. The radius of the electron's circle will be larger than the radius of the proton's circle.

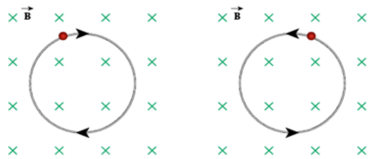
d. It is not possible to determine.

Q11

A proton and an electron are moving along circular paths with equal diameters, in a uniform magnetic field. Which diagram correctly presents the motion of the proton? Select one answer

o The right diagram

o The left diagram



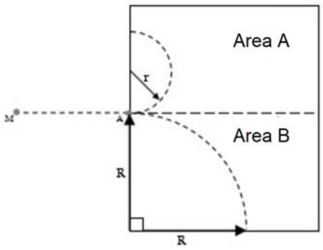
Q12

A proton and an electron are moving along circular paths with equal diameters, in a uniform magnetic field. Which particle is moving with a greater speed? Select one answer

o The electron

o The proton

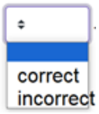
Introduction to Q13-Q18: The diagram presents two rectangular areas. In each of the areas there is a magnetic field perpendicular to the diagram plane. However, it is not known whether it is directed “into the page” or “out of the page”. The magnitude of the magnetic field is equal in both areas and its value is B. Two charged particles q1 q2 exit from point M and move on the page plane at a constant speed v as shown in the diagram. The particles enter the border between the two areas at point A. The diagram presents the particles’ paths with r < R. It is known that q2 has a positive charge q. The charge of q1 is negative and its absolute value is larger than that of q2.
The particles’ masses are identical and its magnitude is m. All forces acting on the particles, other than the magnetic force, can be considered negligible.



Q13

Select correct or incorrect beside each statement:

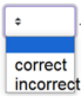
- The radius of the motion of particle q1 is necessarily greater than the radius of the motion of particle q2.
- Charge q2 moves in area A.



Q14

Select correct or incorrect beside each statement:

- The direction of the magnetic field in area A is into the page plane.
- The direction of the magnetic field in area B is into the page plane.



Q15

Express the mass of the particles using the parameters:
R, B, q, v.

m=

Q16

Express the charge q1 using the parameters:
r, R, q.

q1=

Q17

Express the time spent by charge q1 in the area in which it moves using the parameters v & r. Replace Π by pai.

t=

Q18

Express the time spent by charge q2 in the area in which it moves using the parameters v & R. Replace Π by pai.

t=

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