FORMATIVE ASSESSMENT METHODS IN SCIENCE: FINDINGS FROM ASSIST-ME

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Formative assessment

Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers and learners, in order to make decisions about next steps in instruction

(Black & William, 2009).

Aims of formative assessment

- Monitor the learning process and the evolution of students' understanding
- Provide feedback to the students on:
  - Learning objectives
  - Where their current work is at, with respect to the learning objectives
  - What they need to do in order to attain the learning objectives
- Provide feedback to the teacher for designing subsequent steps in the teaching-learning process.

Features of Formative assessment

Formative assessment can be:

- *formal*, focusing on obtaining information about student learning using specific tools,
- or *informal*

and, also,

- *planned*
- or *spontaneous*, taking place whenever possible, in any student–teacher interaction.

(Bell and Cowie, 2001)

Some (formative) Assessment Methods

- Written feedback
- Self-assessment
- Peer-assessment
- Assessment conversations
  - structured assessment dialogues
  - interactions 'on the fly'

I will provide examples with

- Written feedback: Diagnostic Tests
- Peer-assessment
- Assessment Conversations: interactions 'on the fly'

Written Feedback: Diagnostic Test

Diagnostic Tests have been extensively used in SER and reformed teaching

- To elicit student ideas
- To help students consciously commit to specific ideas/perspectives so that they can subsequently be negotiated
- To focus students' attention and discussions on pertinent topics and phenomena
- As pre-tests, to monitor students' conceptual baselines

Example of a Diagnostic Test

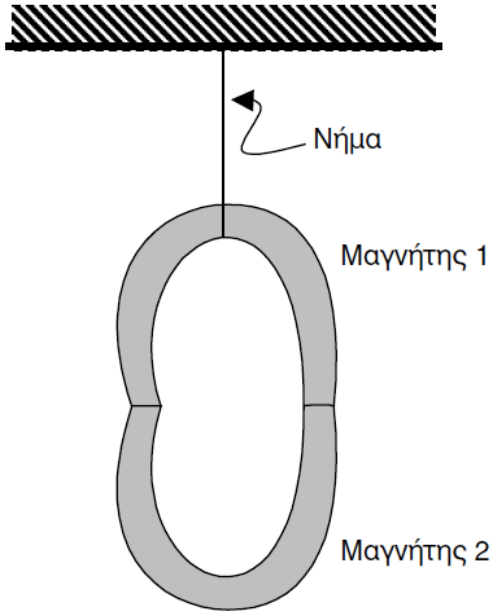
Contact and non-contact forces

A magnet is supported by another magnet as shown at right.

Draw a free-body diagram for magnet 2.

The label for each of the forces on your diagram should indicate:

- the type of force (e.g., gravitational, normal),
- the object on which the force is exerted, and
- the object exerting the force.



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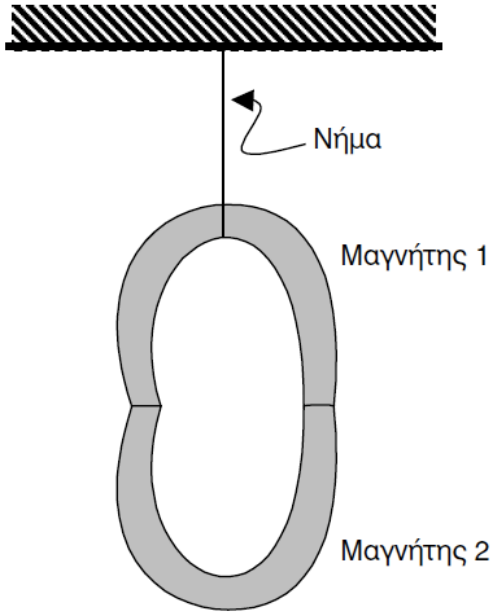

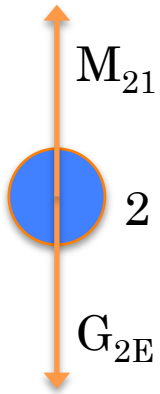

Diagnostic Test: Contact and non-Contact Forces

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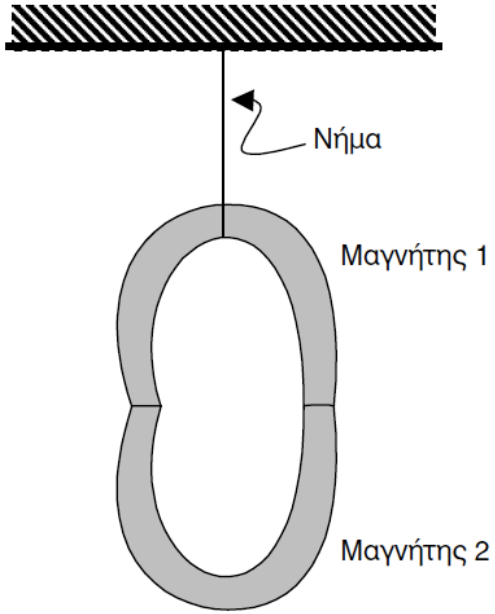
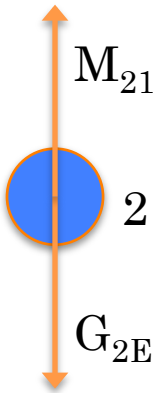


Suppose that the magnets were replaced by stronger magnets of the same mass.

Does this change the free-body diagram for magnet 2?

If yes, sketch the new free-body diagram and describe how the diagram changes.

If no, explain why it does not.



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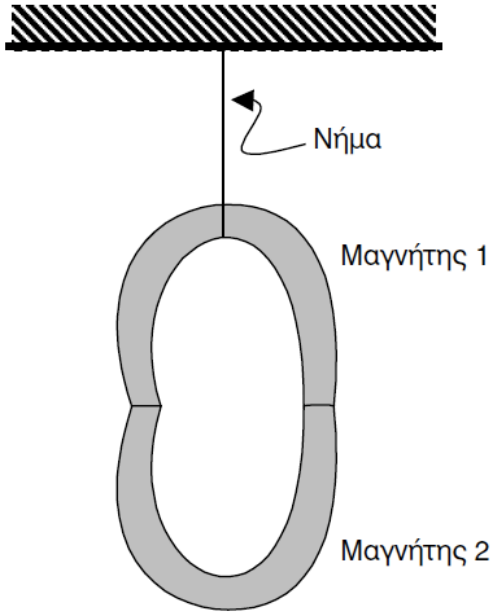
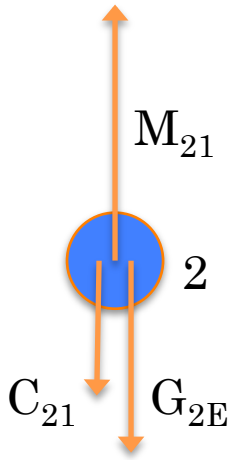


Diagnostic tests can tell us (and the students) a lot about:

- student understanding,
- students' competence with representations and inference,
- student reasoning…



WHY FOCUS ON ASSESSMENT ?

Assessment clarifies the intended learning objectives of a lesson, or programme, or course.

"… by its very nature assessment *reduces ambiguity*. The fifth-grade mathematics standard for many states requires students to be able to compare two fractions to find the larger, but when we assess, we have to decide which pairs of fractions should be included and which should not.

… In fact, the choice of the fractions to be compared makes a huge difference to the rate of student success" (p. 254)

(From: Wiliam, D. (2010). What counts as evidence of educational achievement? The role of constructs in the pursuit of equity in assessment. *Review of Research in Education*, 34, 254-284.)

ASSIST-ME: STEM COMPETENCES

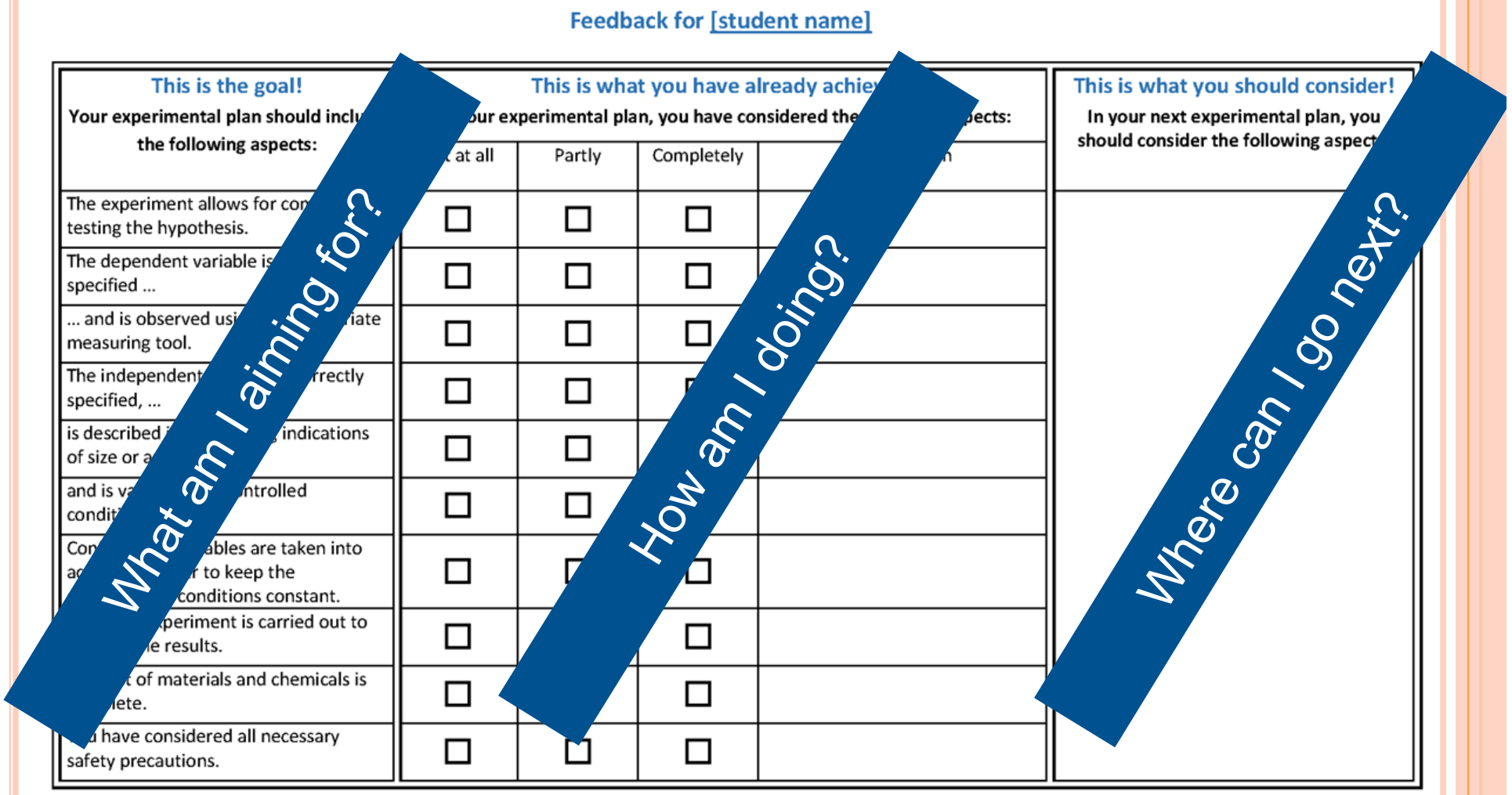
- Empirical investigations in science
- Problem solving in mathematics
- Design in engineering / technology
- Argumentation
- Modeling
- Innovation

Teaching Tools: Written Feedback

Feedback for [student name]

This is the goal! Your experimental plan should include the following aspects:	**This is what you have already achieved!** In your experimental plan, you have considered the following aspects:				**This is what you should consider!** In your next experimental plan, you should consider the following aspects:
	Not at all	Partly	Completely	Justification	
The experiment allows for completely testing the hypothesis.	☐	☐	☐		
The dependent variable is correctly specified ...	☐	☐	☐		
... and is observed using an appropriate measuring tool.	☐	☐	☐		
The independent variable is correctly specified, ...	☐	☐	☐		
is described in detail using indications of size or amount ...	☐	☐	☐		
and is varied under controlled conditions.	☐	☐	☐		
Confounding variables are taken into account in order to keep the experimental conditions constant.	☐	☐	☐		
A control experiment is carried out to confirm the results.	☐	☐	☐		
Your list of materials and chemicals is complete.	☐	☐	☐		
You have considered all necessary safety precautions.	☐	☐	☐		

Teaching Tools: Written Feedback



Feedback for [student name]

This is the goal! Your experimental plan should incl… the following aspects:	This is what you have already achie… our experimental plan, you have considered the… pects:				This is what you should consider! In your next experimental plan, you should consider the following aspect…
	…t at all	Partly	Completely	…n	
The experiment allows for co… testing the hypothesis.	☐	☐	☐		
The dependent variable is… specified …	☐	☐	☐		
… and is observed usi… …riate measuring tool.	☐	☐	☐		
The independent… …rrectly specified, …	☐	☐	☐		
is described i… …indications of size or a…	☐	☐			
and is va… …ntrolled conditi…	☐	☐			
Con… …ables are taken into ac… …r to keep the …conditions constant.	☐	☐	☐		
…periment is carried out to …e results.	☐		☐		
…t of materials and chemicals is …lete.	☐		☐		
…d have considered all necessary safety precautions.	☐	☐	☐		

What am I aiming for?

How am I doing?

Where can I go next?

http://assistme.ku.dk/resources/deliverables

Dimensions of Teacher Written Feedback

- Indication of student's level of attainment
- Justification offered about the judged level of attainment
- Guidance provided to the student(s) on how to progress
- Encouragement, respect and emotional connection [Affective dimension]
- Accessibility of the language used [Simplicity]

Critical Dimensions of Written Feedback

- Indication of student's level of attainment
- **Justification offered about the judged level of attainment**
- Guidance provided to the student(s) on how to progress
- **Encouragement, respect and emotional connection [Affective dimension]**
- Accessibility of the language used [Simplicity]

- **Students' subsequent use of the feedback in follow-up activities**

FA Approach II: Peer Assessment

What is Peer Assessment (PA)?

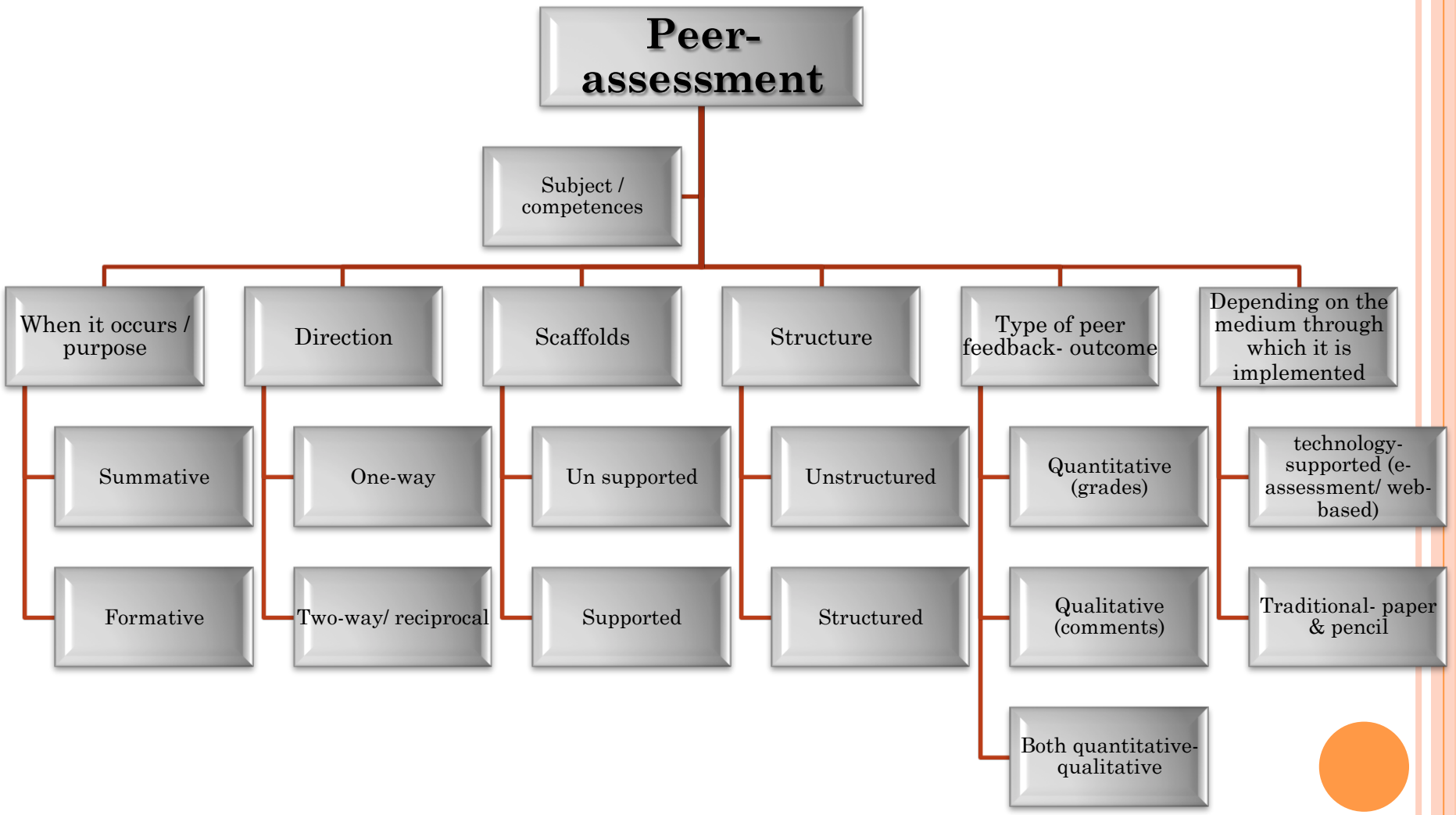
- PA is an educational arrangement where students judge their peers' performance by providing grades and offering written or oral feedback.
(Topping, 1998)

- When employed formatively, peer-assessment can improve students' learning and metacognition.
(Chen, et al., 2009; Crane & Winterbottom, 2008; Tsivitanidou & Constantinou, 2016; Tsivitanidou et al., 2011)

WHY PEER-ASSESSMENT?

- Peer-assessment
  - As an innovative assessment approach.
  - As a learning tool.
- Students could benefit from peer-assessment by:
  - Using the peer feedback produced to improve learning artifacts and advance their understanding and performance.
  - Reflecting on the experience of assessing and being assessed.

Features of Peer-Assessment



STUDENTS' STRATEGIES IN PA

- What do students actually do while they adopt the role of the peer assessor?
- What are the heuristics that students employ in order to provide feedback?
- How do these heuristics associate with students' learning gains but also the feedback they produce in a science inquiry-based learning environment?

Tsivitanidou, O., & Constantinou, C. (2016). A study of students' heuristics and strategy patterns in web-based reciprocal peer assessment for science learning. *The Internet and Higher Education. 12,* 12-22, DOI:10.1016/ j.iheduc.2015.11.002

STUDENTS' STRATEGIES IN PA

PA in Study 1	PA in Study 2
Unsupported: No scaffolds (e.g. no criteria) offered to students while doing PA.	Supported: Scaffolds (e.g. criteria in the form of rubrics) offered to students while doing PA.
Unstructured PA: students were free to initiate a feedback-dialogue whenever they wished to do so.	Structured PA: students assessed the artifacts of a peer-group at the end of the teaching sequence. Pairs of groups were determined by the teacher.
Only peer-feedback offered.	Students received peer- and teacher-feedback.
Tsivitanidou, O., & Constantinou, C. (2016). A study of students' heuristics and strategy patterns in web-based reciprocal peer assessment for science learning. *The Internet and Higher Education. 12,* 12-22, DOI:10.1016/ j.iheduc.2015.11.002	Tsivitanidou, O., & Constantinou, C. (2016). Undergraduate Students' Heuristics and Strategy Patterns in Response to Web-Based Peer and Teacher Assessment for Science Learning. In Malcolm Vargas (Ed.), *Teaching and Learning: Principles, Approaches and Impact Assessment*. (pp. 65-116). New York: Nova Science Publishers. ISBN: 978-1-63485-228-9

Study 1 findings

- Students' learning gains were associated with their actions as peer-assessees and their attitudes towards peer feedback.
  - Engaged assessees had more learning gains, as compared to disinterested assessees.

Study 2: Identified Profiles

- Peer-assessor profiles
  - Autonomous assessors
  - Informed assessors
- Peer-assessee profiles
  - Teacher trusting assessees
  - Teacher trusting and skeptical towards peer feedback assessees
  - Teacher and peer trusting assessees

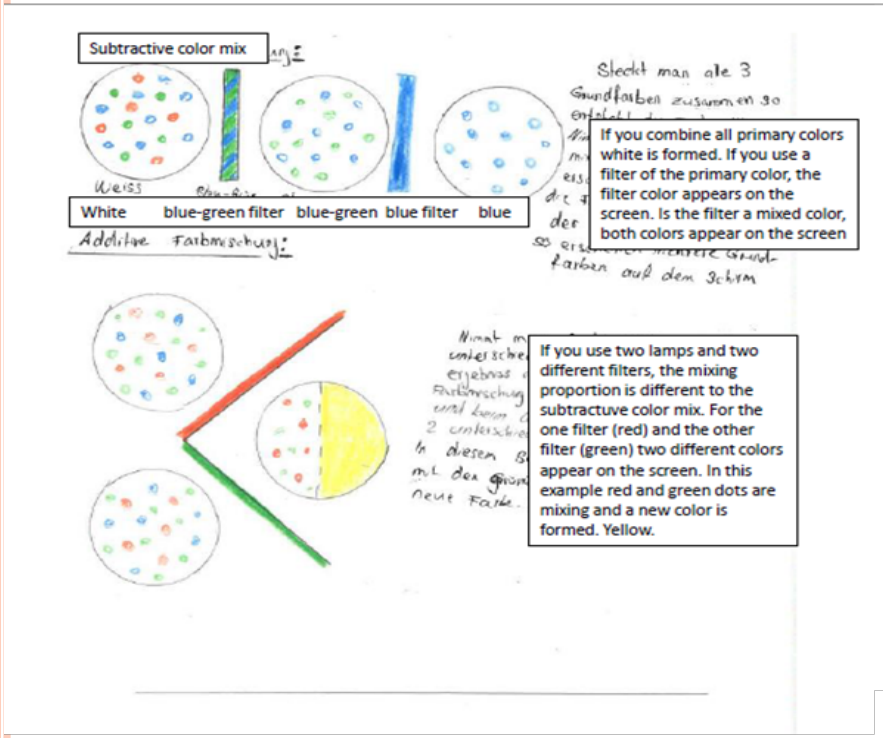
Study 2: Main Findings

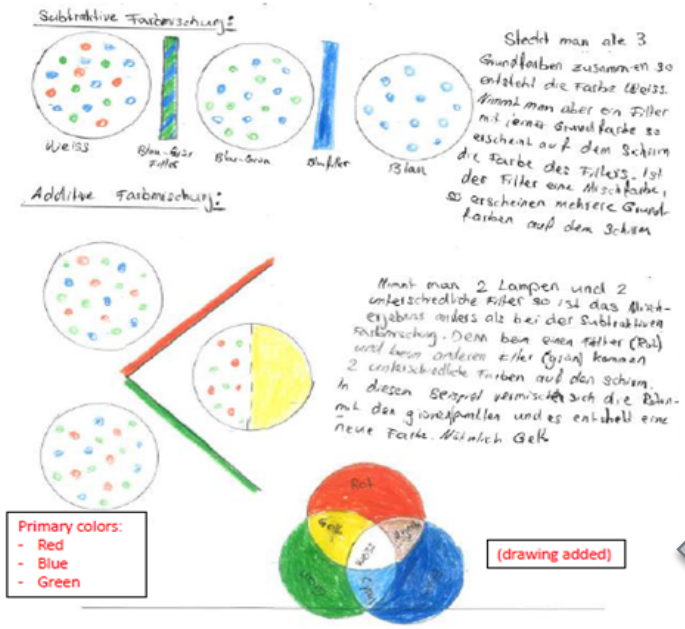
- All students had positive learning gains at the end of the intervention, regardless of the strategies they had followed.
- Informed assessors offered more guidance in their peer-feedback comments compared to the guidance offered by autonomous assessors.
- Assessees' strategies were found to be associated with the structural components of peer and teacher-feedback received.
- Time pressure was a critical factor that affected assessees' actions.

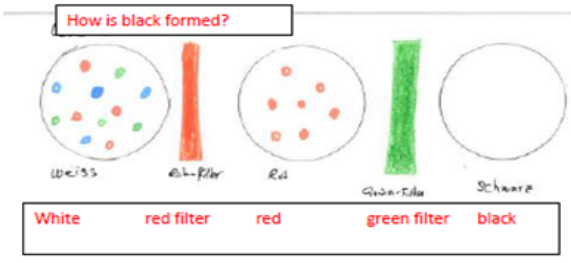
An example: PA in a Physics class

- **Focus:** Peer-assessment in construction, evaluation and revision of representations.
- **Subject:** Physics, upper secondary school (common core)
- How can peer-assessment potentially facilitate students' understanding of scientific concepts and phenomena?

Peer Assessment with Light and Colour (initial and revised representations of group 10)







CONCLUSIONS

- Reciprocal peer-assessment, as experienced in the roles of assessor and assessee, can facilitate student learning, especially in the mode of learning from peers
- Peer-assessment: as a learning tool for learners

However, attention should be given to:

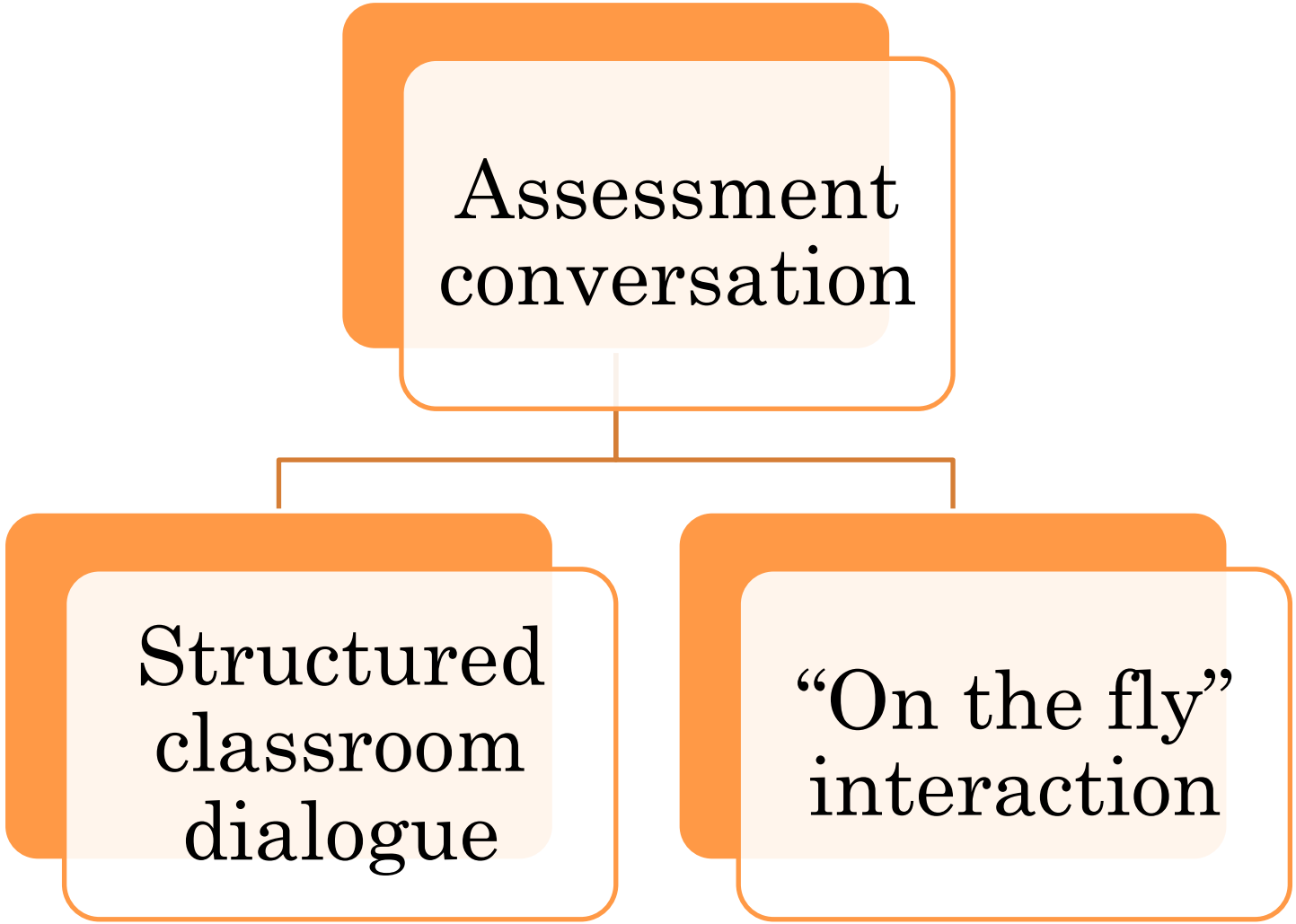
- ✓ Establishing a common understanding of learning objects, before PA.
- ✓ Offering adequate scaffolds, especially when students are novices in PA.
- ✓ Encourage the students in appreciating the benefits of PA: positive attitudes

FA Approach III: Assessment conversation

- An assessment conversation is a teaching-learning dialogue that embeds assessment into the activity structure of the classroom (Duschl, 2008).

The teacher

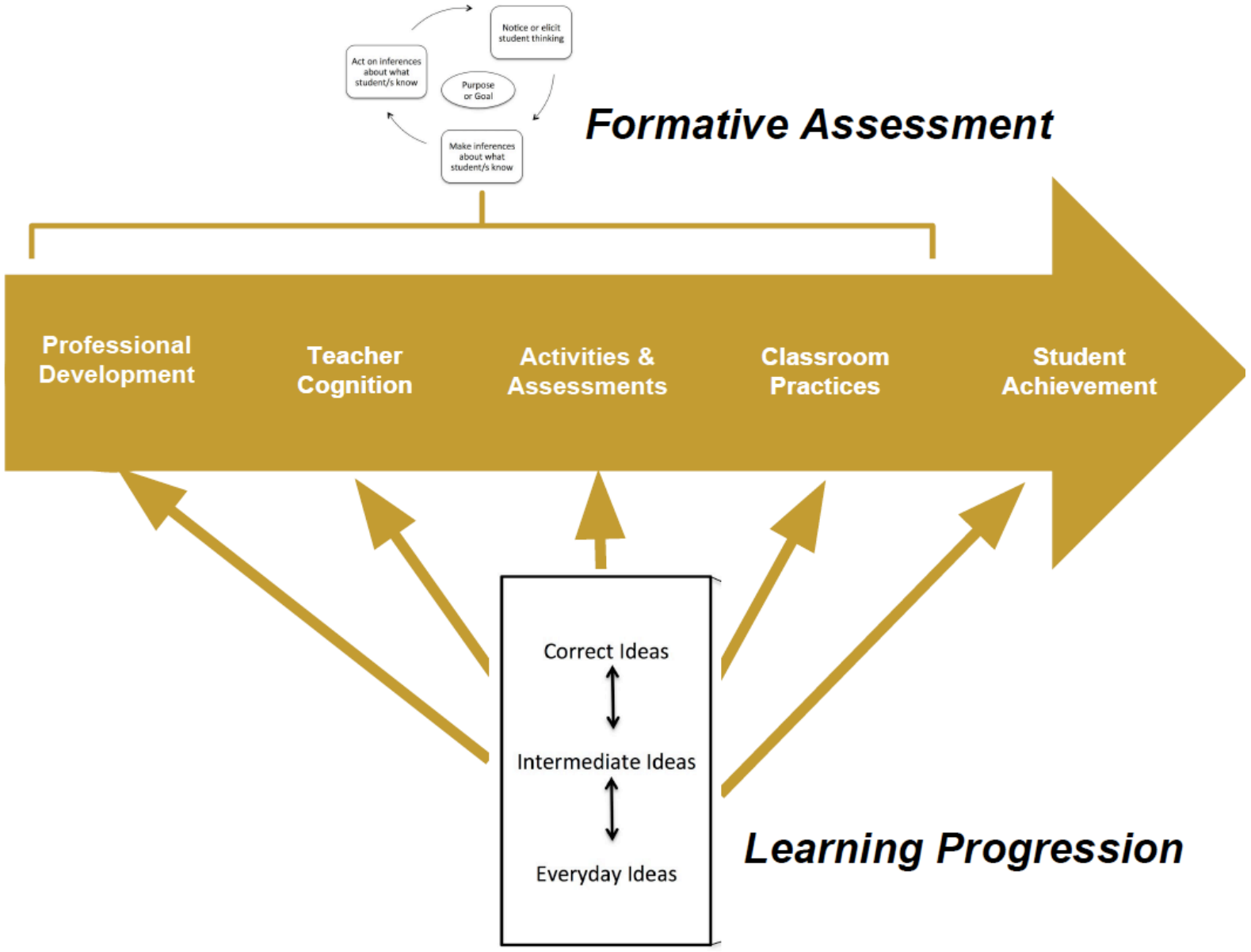
- Elicits student ideas
- Provides feedback
- Steers the discussion to facilitate learning (Duschl, 2010).


Assessment conversation
Structured classroom dialogue
“On the fly” interaction

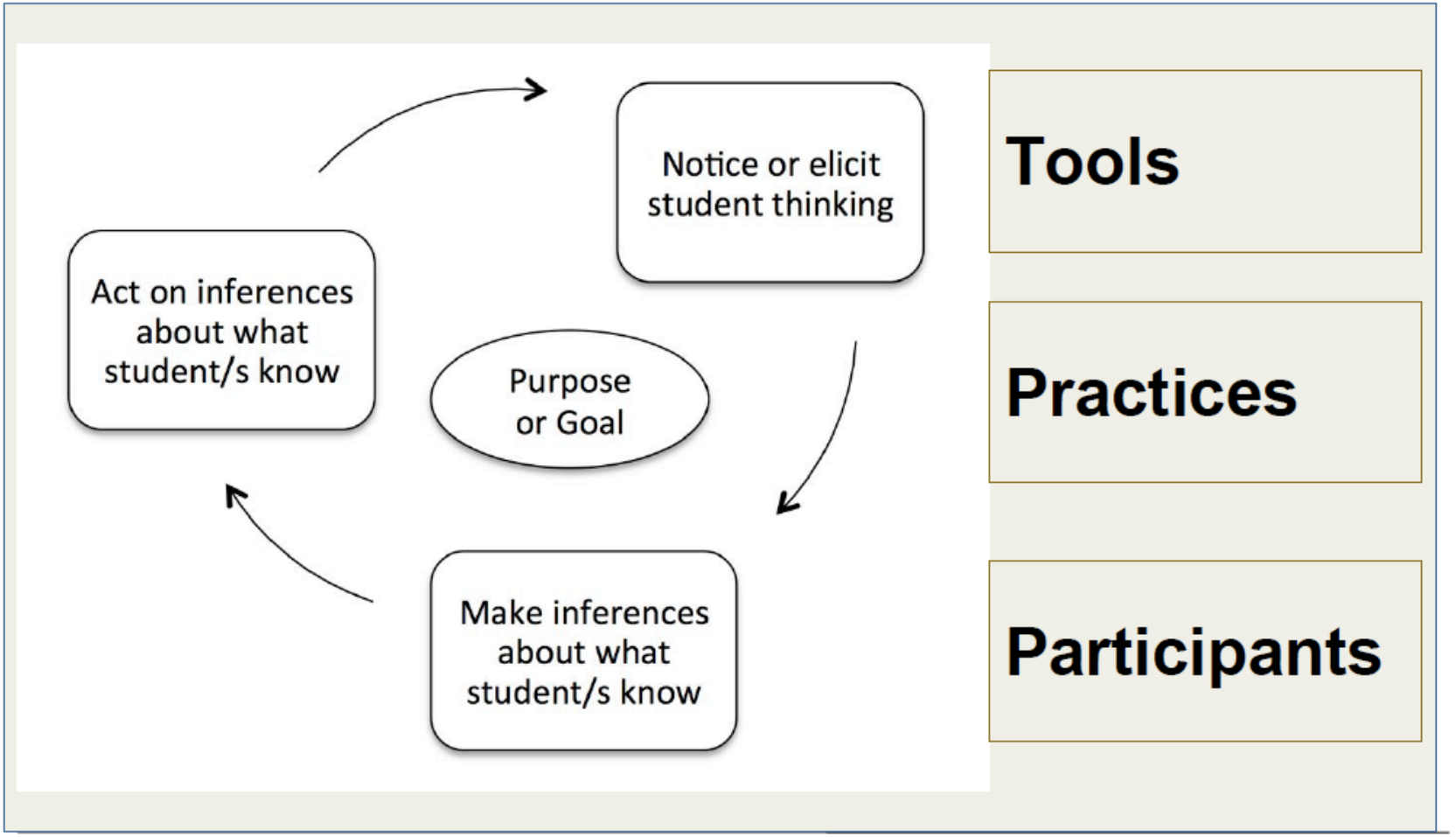
"*On the fly" interaction*

"*On the fly" interactions* for assessment occur spontaneously during the course of a lesson when "teachable moments" arise in the classroom and teachers have to make inferences on a moment-by-moment basis (Heritage, 2007).

"On the fly" interaction



Formative Assessment



Characteristics of "on the fly" interactions

- Teacher seeks to create and sustain assessment discourse (Duschl, 2008)
- From the perspective of the students, there is no formal collection of data or use of specific tools.
- Formative assessment takes place spontaneously through the teacher's interaction with students.

AFFORDANCES OF *"ON THE FLY"* INTERACTIONS

- The teacher is able to identify difficulties (e.g., conceptual or reasoning) encountered by the students and seize opportunities to timely address them (Bell & Cowie, 2001; McConnell, Steer, Owens, 2003).
- The teacher can steer the discussion so as to help students progress (e.g. by providing useful clarifications or posing questions to problematize the discussion and support reflection) (Black&Wiliam, 1998; Duschl, 2000, 2003).
- Allows the teacher to dynamically adapt instruction so as to become more aligned with students needs, as they emerge during the interactions (Duschl, 2010).

CHALLENGES WITH *"ON THE FLY"* INTERACTIONS

Taking advantage of assessment opportunities in real time, is not easy for teachers; often, much of the available information is not used effectively (Hickey, 2009).

- There is a lot of complexity and richness in classroom discussion in terms of the information that is exchanged
- Teachers are not familiar with using student-generated information to guide instructional decision-making in a dynamic manner (Duschl, 2008).
- Teachers have other, varied priorities and are not always consciously aware of their own engagement in unplanned or interactive formative assessment (Bell & Cowie, 2001).

Research on coding interaction during assessment dialogues

Patterns in teacher-student interaction (Cazden, 2001):

- Initiation, Response, Evaluation (IRE)
- Initiation, Response, Feedback (IRF)
  - Teacher's questions are often not authentic.
  - Students' contribution is often procedural instead of authentic.
  - The teacher has a high level of authority.

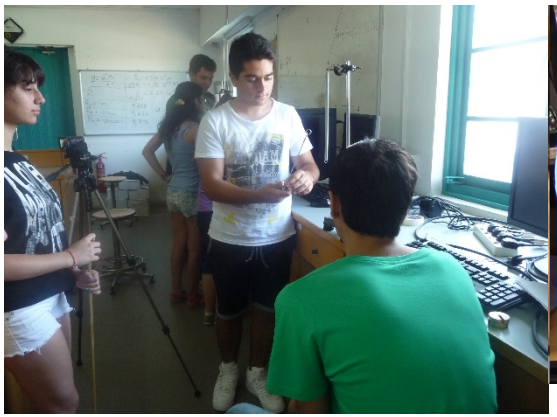
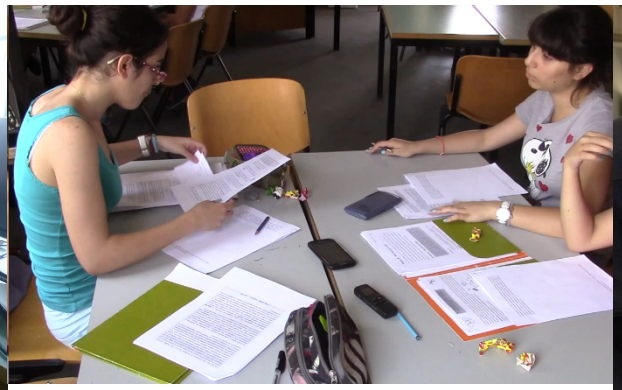
  (Nystrand & Gamoran, 1991).
- Elicit, Confront, Resolve (ECR)
- Initiate, Sustain, Problematize, Bring Closure
- Elicit, Student responses, teacher Recognizes responses, teacher Use (ESRU)

  (Ruiz-Primo & Furtak, 2006)

Research questions

1. What patterns can we identify in “on the fly interactions” between the teacher and the students when the teacher is interested in using the available information for formative assessment?
2. What factors facilitate or impede teachers’ attempts to use “interactions on the fly” in order to guide students towards the inquiry learning goals?
   - What are the emergent factors that seem to afford productive teacher feedback?
   - What are the various types of missed opportunities encountered in the interactions on the fly? and what are possible interpretations for why these opportunities were missed by the teacher?
3. How can we integrate disciplinary content goals in the analysis of the dialogue that unfolds in the classroom?
4. How does the teacher’s responsiveness to the students’ contributions to the dialogue relate to the conceptual coherence of the dialogue?

PROJECT ASSIST-ME


Competence: Empirical investigations in science
Subject Matter: Physics
Educational Level: Upper Secondary (Common Core)

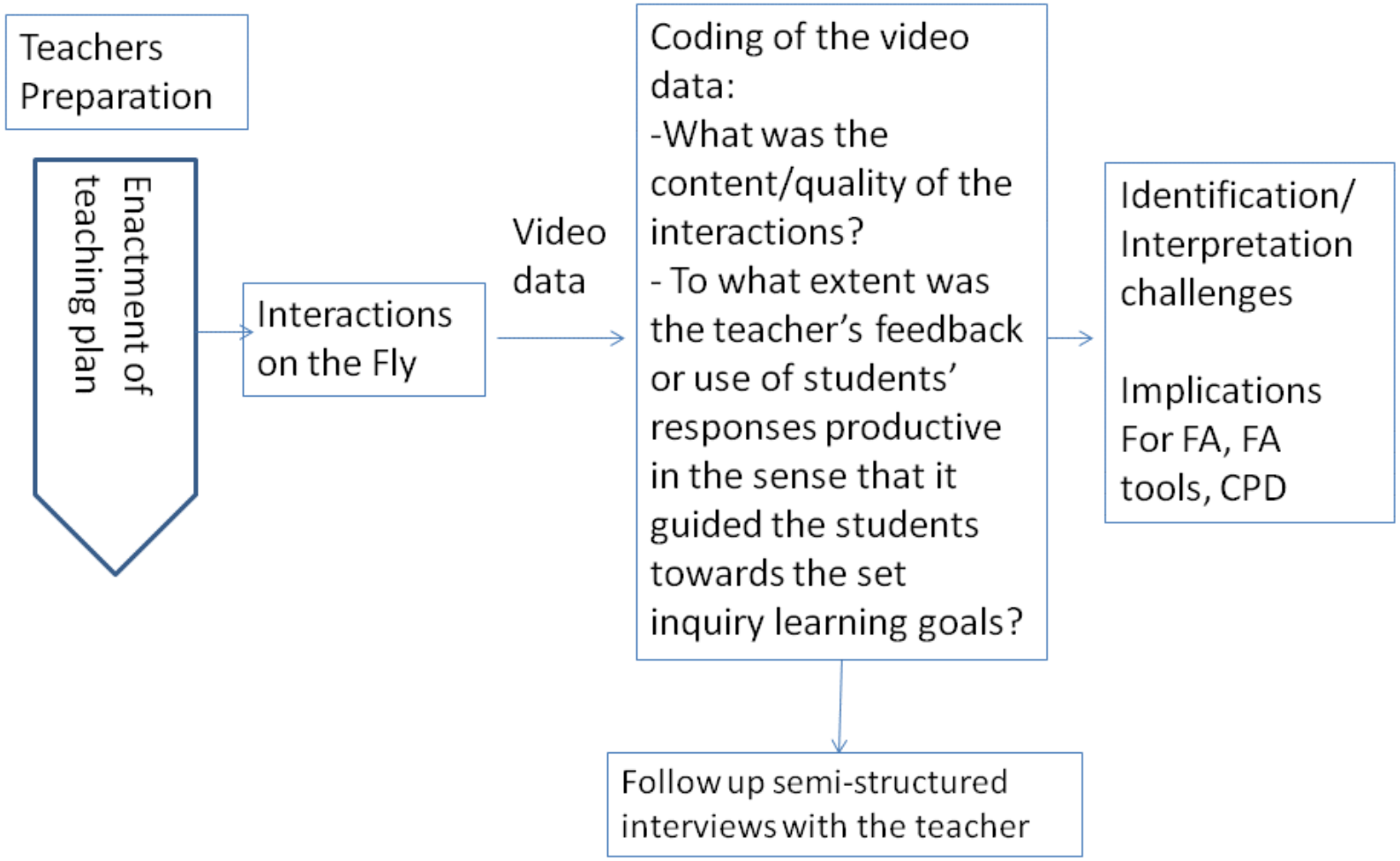
Assessment Method:
Marking
(Grading and Written Comments)

Research Design II

Assessment Method:
Interactions on the fly

Research Design I

Research Design (I)



- During the enactment students are engaged in classroom discussion
- The teacher seeks to create and sustain assessment discourse

Instructional Context

Subject Matter: Physics
Topic: Newton's Laws, freefall and motion along an inclined plane

Students undertook to conduct a sequence of two investigations of whether (and how?) different variables influence:

- the speed at which an object reaches the ground when released from some height,
- The speed attained by an object after it rolls down an inclined plane.

METHOD: DATA ANALYSIS

The analysis is applied on three levels (Tiberghien & Malkoun, 2009):

- Micro-scopic: Line by line coding of each teacher's or student's contributions to the dialogue.
- Meso-scopic: Characterization of each cycle of interactions as a complete or incomplete ESRU cycle.
- Macro-scopic: The use of the emerging information is evaluated at the level of a whole episode (part of the dialogue with a particular theme under discussion).

METHOD

- Interactions between teachers and students are coded using the ESRU scheme, where:

  E: Elicit students' ideas

  S: Students' response

  R: Teacher recognizes student responses

  U: Teacher uses information collected

  (Ruiz-Primo & Furtak (2006)

Method

- We sub-categorize these instances into the various ways they occur in class; for example, the different ways a teacher might use for eliciting information
- Look for patterns in possible factors that have facilitated the completion of ESRU cycles
- Identify instances in which the cycle happened to break and elaborate on the different reasons underlying this.
- Identify and categorize instances of either not utilizing contributions from students or not doing so in a productive manner (missed opportunities)

Classroom Observations

Trial	Ed. level	Competence	Subject	Topic	No. of Students
1	Upper Secondary (vocational)	Investigation	Physics	Free fall	12
2	Upper Secondary (Lyceum)	Investigation	Physics	Newton's laws	43 (2 classes)
3	Upper Secondary (Summer School)	Investigation	Physics	Bungee jumping	33 (2 classes)

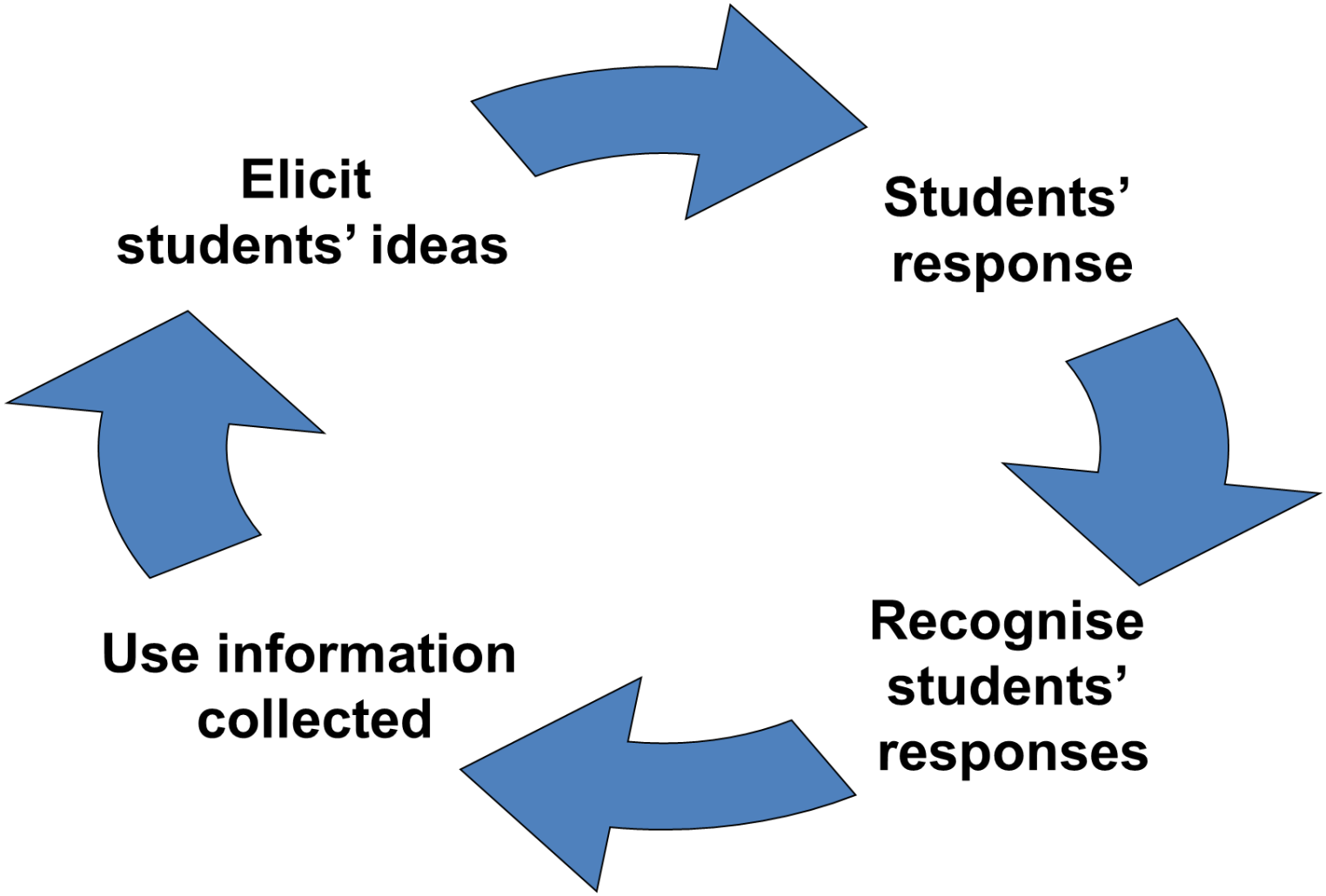
RESULTS

1. What patterns can we identify in "on the fly interactions" between the teacher and the students when the teacher is interested in using the available information for formative assessment?

Variant of ESRU cycle	Frequency (1st Impl.)	Frequency (2nd Impl.)	Frequency (3rd Impl.)
Complete ESRU	41 (65%)	77 (37%)	71 (70%)
Incomplete ESR or ES	22 (35%)	130 (63%)	30 (30%)

⟶ further insights into the patterns characterizing the interactions between teacher and students: identification and description of the variation within each of the four elements
(e.g. sub-categories of E, S R U)

ESRU Scheme


Elicit students' ideas
Students' response
Recognise students' responses
Use information collected

SUBCATEGORIES: *ELICIT*

E1	Teacher poses a question to elicit students` reasoning about a new (although related) concept/idea/relation
E2	Teacher asks students to offer an example or report data
E3	Teacher repeats a prior question
E4	Teacher asks for clarification
E5	Teacher suggests a false concept/idea/relation and encourages students to reflect on it

SUBCATEGORIES: *STUDENTS' RESPONSE*

S1	Student suggests a concept/relation in response to question posed by the teacher
S2	Student offers justification for his/her reasoning
S3	Student provides an example or reports data
S4	Student explicates an inference about an aspect of the topic under discussion
S5	Student poses a question to the teacher related to the topic under discussion
S6	Student provides a "yes/no" answer
S7	Student expresses ignorance

SUBCATEGORIES: RECOGNIZE

R1	Provision of affirmation / encouragement
R2	Teacher readily offers the right answer to a question posed by himself/herself or by a student.
R3	Provision of disconfirmation / creation of doubt
R4	The teacher acknowledges a contribution made by the students

SUBCATEGORIES: *USE*

U1	Teacher suggests an activity that could help students resolve a specific (conceptual) issue
U2	Teacher seeks to focus students' attention on something with the intent to facilitate or sustain further discussion (e.g. stated opinions/data/examples)
U3	Teacher seeks to engage students in deeper reasoning on a specific issue (further analysis/explanation)
U4	Teacher seeks closure by articulating the consensus from a series of contributions that were exchanged

Discussion

- The type and number of complete and incomplete cycles observed during the discussions seem to be indicative of the quality of teachers' informal formative assessment practices.
- A closer look at the content of the complete and incomplete cycles suggests that their relative proportion alone does not provide a reliable indication of the quality of the dialogue (from a teaching/learning perspective).

WHY IS ASSESSMENT SO IMPORTANT?

Because there is a very big gap between what is taught and what is learned.

"If what students learned as a result of the instructional practices of teachers were predictable, then all forms of assessment would be unnecessary; student achievement could be determined simply by inventorying their educational experiences. However, because what is learned by students is not related in any simple way to what they have been taught, assessment is a central—perhaps even *the* central—process in education." (p. 254)

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Thank you!

Contact Information

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