A Professional Development Course

for a Chemistry-Infused Quantum Mechanics Curriculum

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I think I can safely say that nobody understands quantum mechanics !

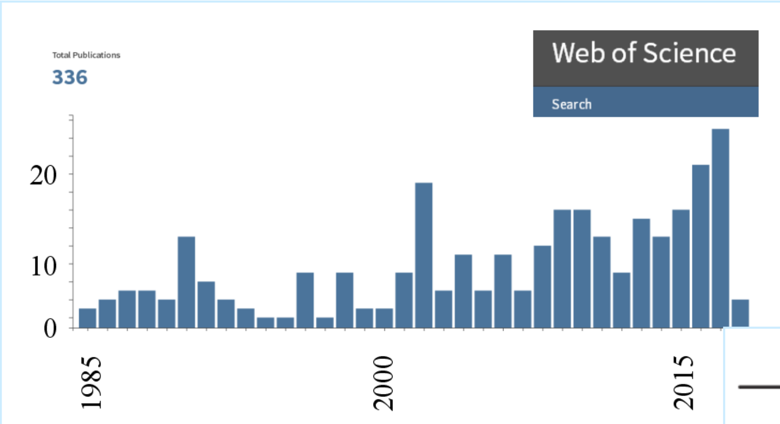
QM is perceived as weird by students

QMB is a project to develop a new teaching-learning sequence for high-school students

This step: the Teachers' training

GIREP-MPTL 2019

Introduction: *Context and motivation*



QM teaching is a topical subject

PHYSICAL REVIEW PHYSICS EDUCATION RESEARCH **15,** 010130 (2019)

Featured in Physics

Analysis of secondary school quantum physics curricula of 15 different countries: Different perspectives on a challenging topic

H. K. E. Stadermann,[1,*] E. van den Berg,[2] and M. J. Goedhart[1]

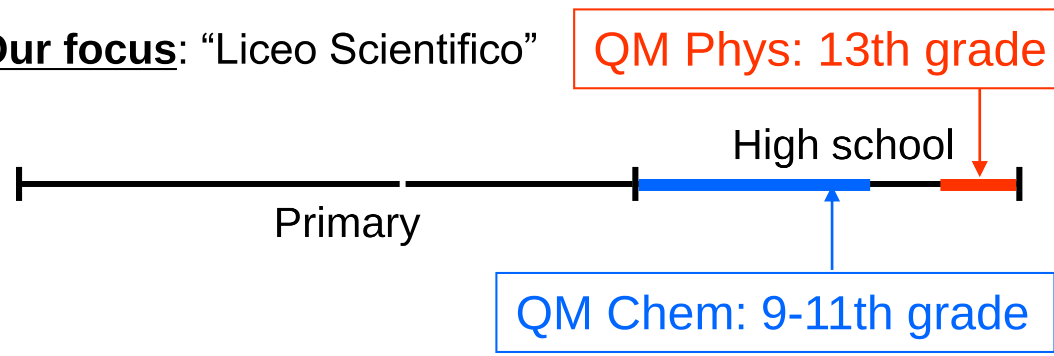
PHYSICAL REVIEW PHYSICS EDUCATION RESEARCH **13,** 010109 (2017)

Insights into teaching quantum mechanics in secondary and lower undergraduate education

K. Krijtenburg-Lewerissa,[1] H. J. Pol,[1] A. Brinkman,[2] and W. R. van Joolingen[3]

Recently QM has been intensified in High School curricula

<u>Our focus</u>: “Liceo Scientifico”



Quantum Mechanics Basis - QMB is based on a <u>multidisciplinary</u> approach

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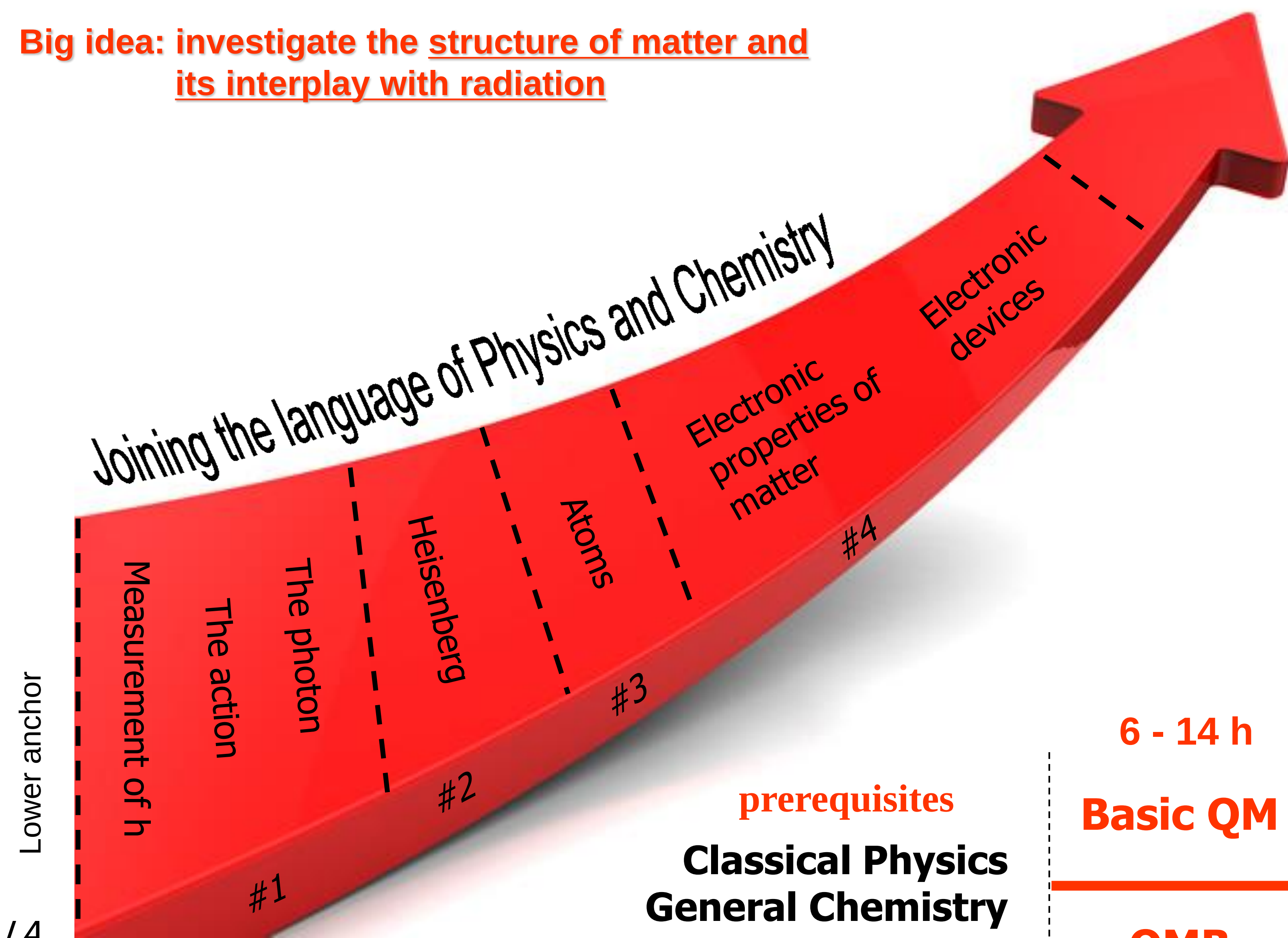
Curriculum design: *The QMB Sequence*

Big idea: investigate the <u>structure of matter and its interplay with radiation</u>

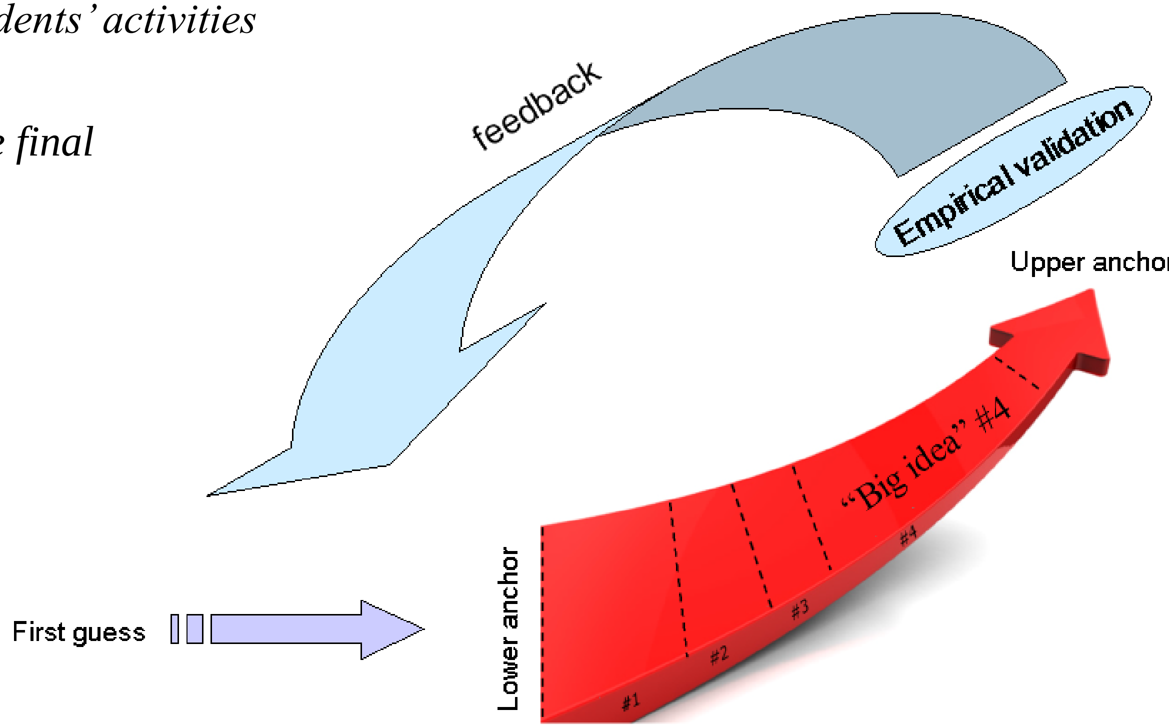


prerequisites	6 - 14 h	
Classical Physics	**Basic QM**	**Wave QM**
General Chemistry	**QMB**	
Lower anchor		

Theoretical framework: *The Teaching Learning Sequences (TLS)*

QMB:

- *has an olistic approach linking students' activities and their expected outcomes*
- *provides full material including the final validation instrument*



2018

First round of QMB: implementation by researchers

Second round of QMB: curricular implementation

2019

2019	1st period	Training course for teachers
	2nd period	Implementation by teachers

Theoretical frame: Psillos & Kariotoglou (2016)

Theoretical framework: *From curriculum in theory to curriculum in use*

The ability of an intervention to produce the desired beneficial effect

Curricular implementation

In expert hands under ideal circumstances: ***Efficacy***
In actual use: ***Effectiveness***

Our research: ***The fidelity of implementation***

Attitude and Inclination

RQ#1	1.	What are the **teachers' perceptions** about QMB multidisciplinary approach?
RQ#2	2.	To what extent are they prone to **accept and actuate** the QMB key concepts?

Sample: Teachers that attended the QMB professional Development Course

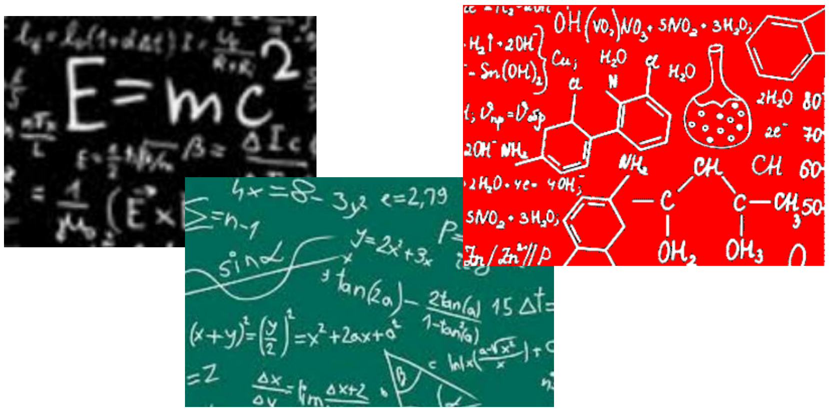
Instruments:

1. the "Fidelity Poll" questionnaire
2. interviews to teachers

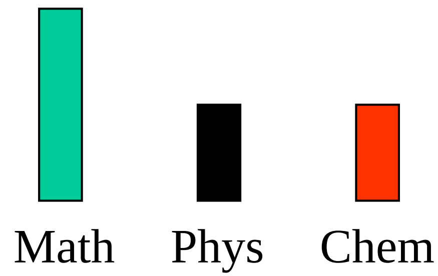
Theoretical frame: Hall & Loucks (1977), Carol L. O'Donnell (2008), Shkedi (1998)

The Professional Development Course

40 h Professional Development Course
40 h Cooperative Experimentation supporting classroom implementation



The sample



27 teachers
15 years experience

<u>Scientific and technological content knowledge</u>

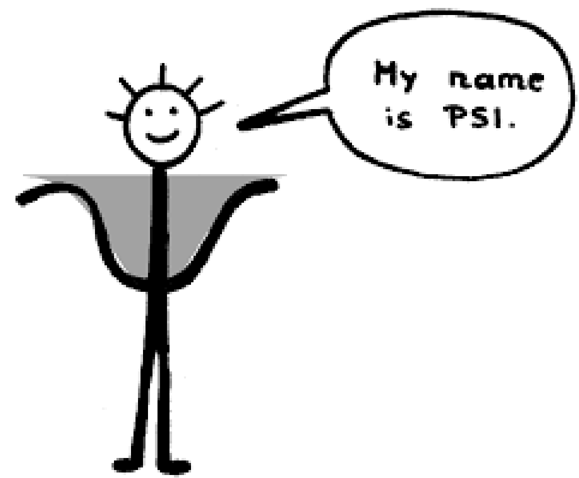
QM basic concepts: from the general rules to the structure of matter

<u>Pedagogical content knowledge</u>

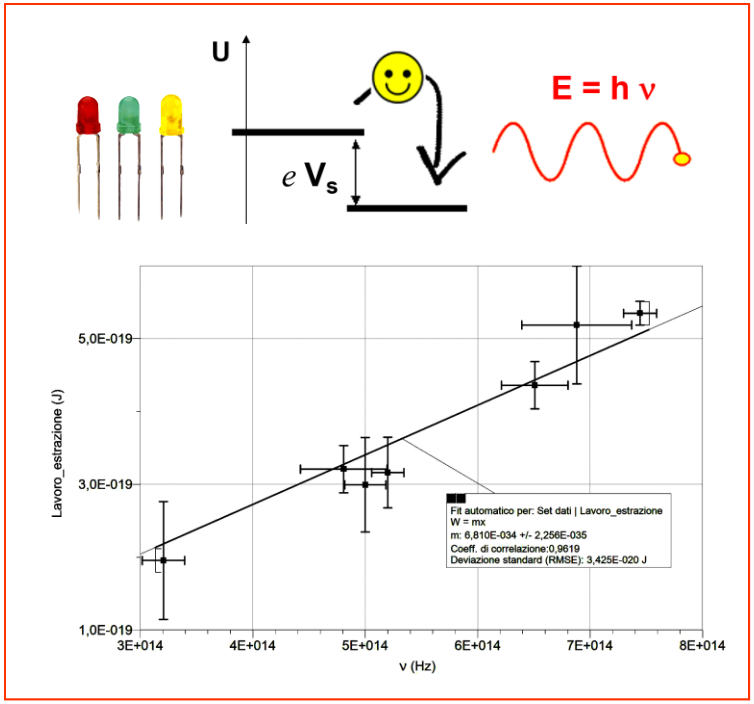
inquiry, experimental evidence-first, representations
socioscientific issues, science practices
instrument for sequence validation and student's evaluation

<u>Adaptation</u>

how to modify the curriculum and the intervention duration
how to chose the deepnings



The key concepts and practices of QMB



Experiment-first

Active experimentation: the measurement of h

Classical vs. Quantum

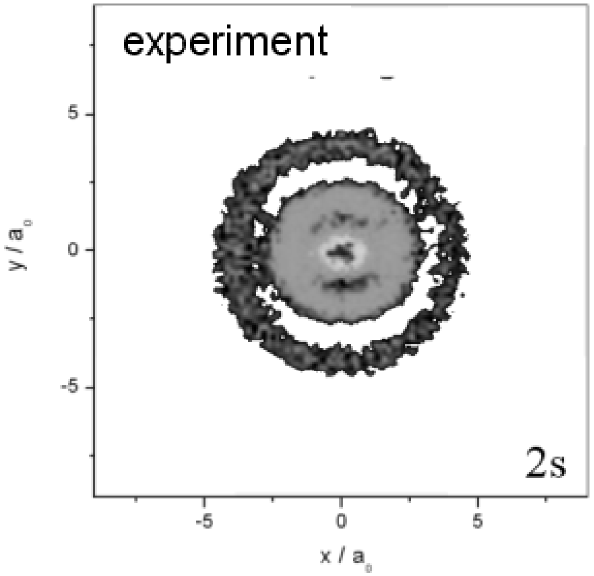
The concept of Theory and of its Domain of validity

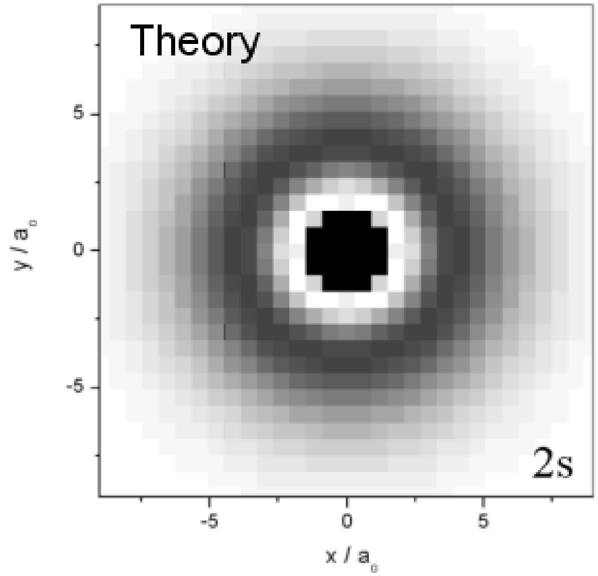
Refuse the "historical approach"

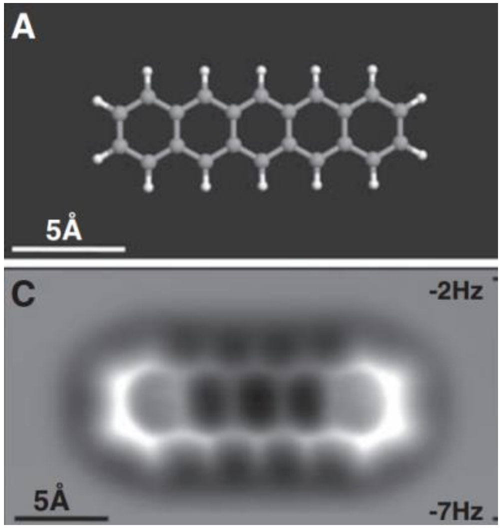
Modern measurements and science practises

Focus on phenomenlogy and socioscientific issues

Large use of representations, low math level







RQ#1 Instruments: *The "Fidelity Poll" questionnaire*

Before classroom implementation

Approval rate on 39 statements in 4 areas

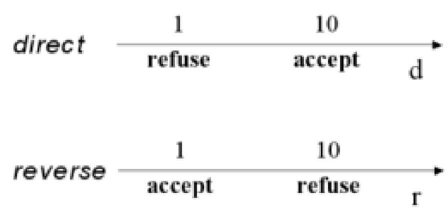
Key issues	How relevant is the ability to interpret **representations**? How relevant is to know the **technological fallouts** of QM?
Contents	How relevant is to show **recent results**, instead of historical ones?
Approach	I cannot introduce QM without its **math formalism** (reversed)
Context & Students	Is BMQ more suitable to **Chemistry** than to **Physics** classes? My students will comment that **QMB is difficult** (reversed)

Reversed

1-10 Likert scale

Both ***coherent*** and ***antithetic*** statements

Likert scale



Fidelity Index

"direct" "reversed"

$$F = \sum_i d_i + \sum_j \left(11 - r_j\right)$$

$$39 \leq F \leq 390$$

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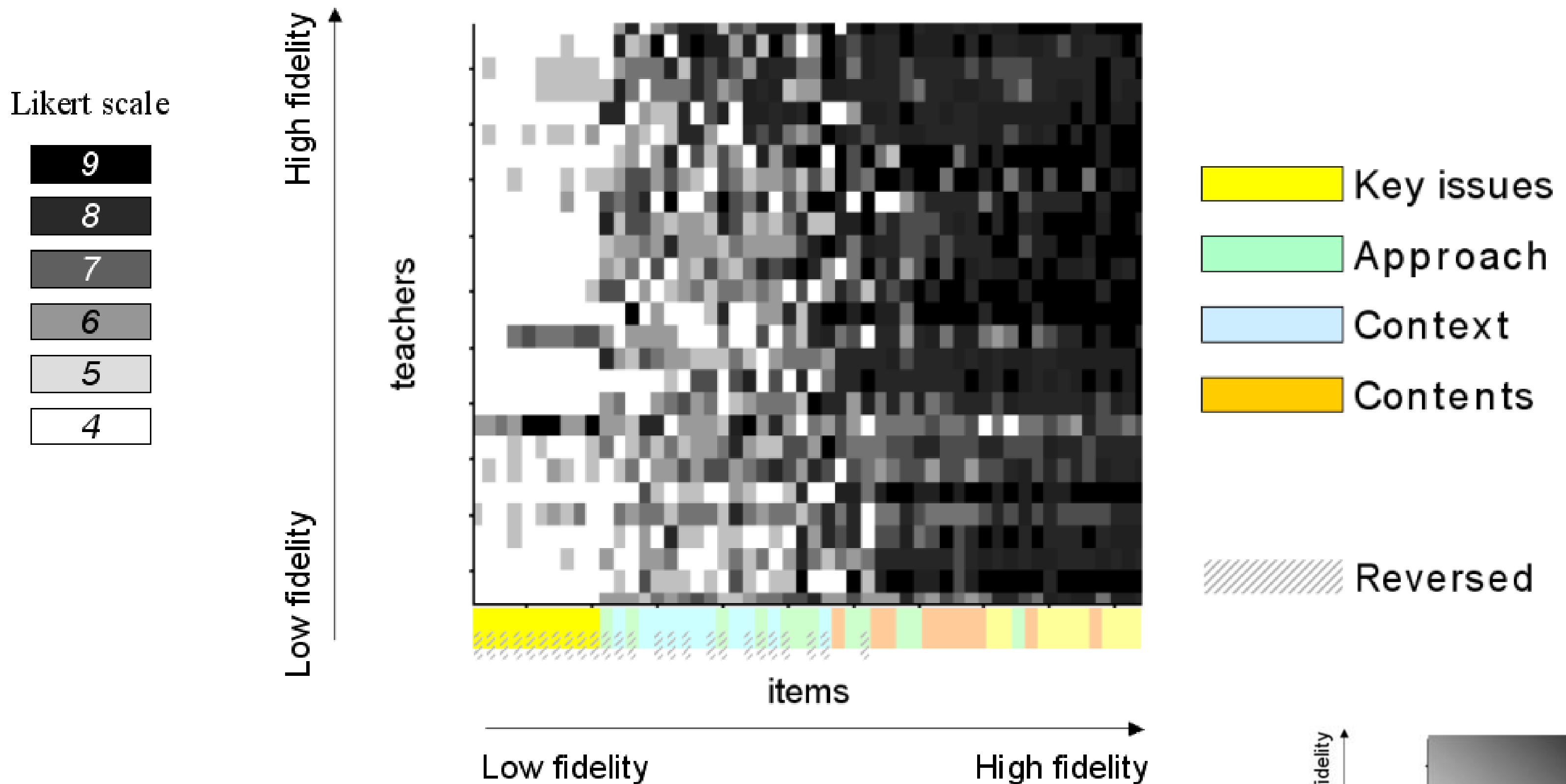
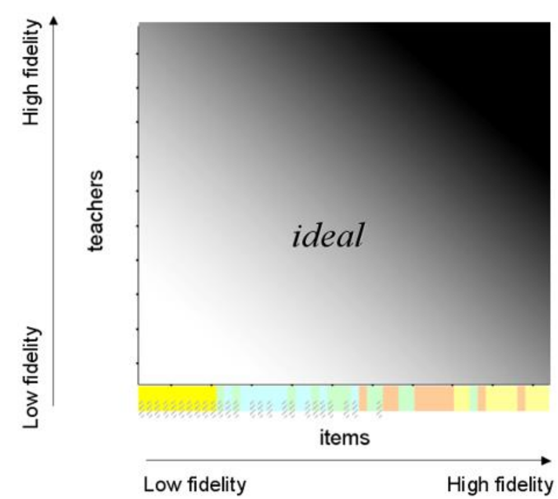
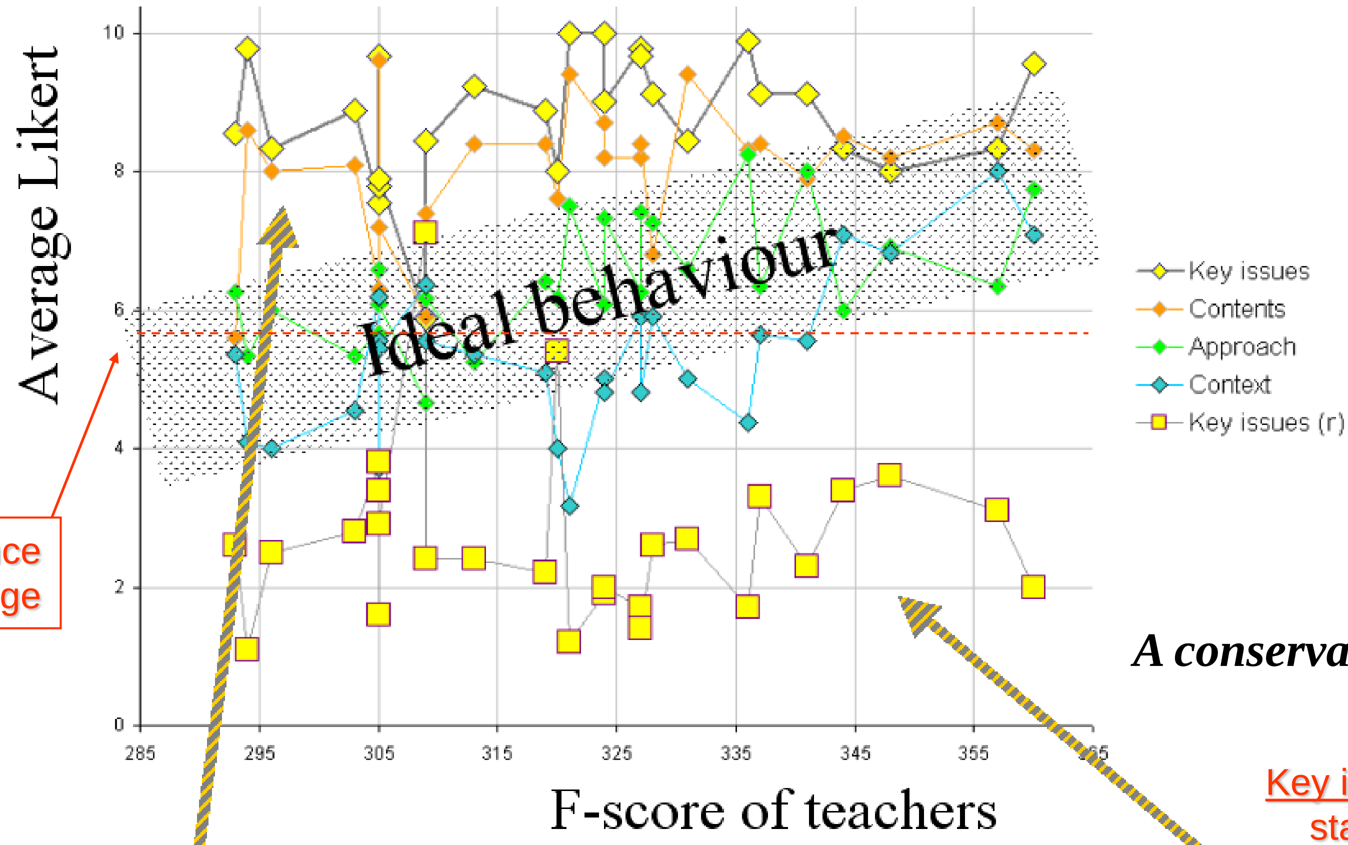
RQ#1 Results: *the Likert Map of the "Fidelity Poll" questionnaire*





RQ#1 Results: *Items average Likert*

Marginal distribution #1



Acceptance edge

A conservative behaviour

Key issues: antithetic statements always earn a poor grade

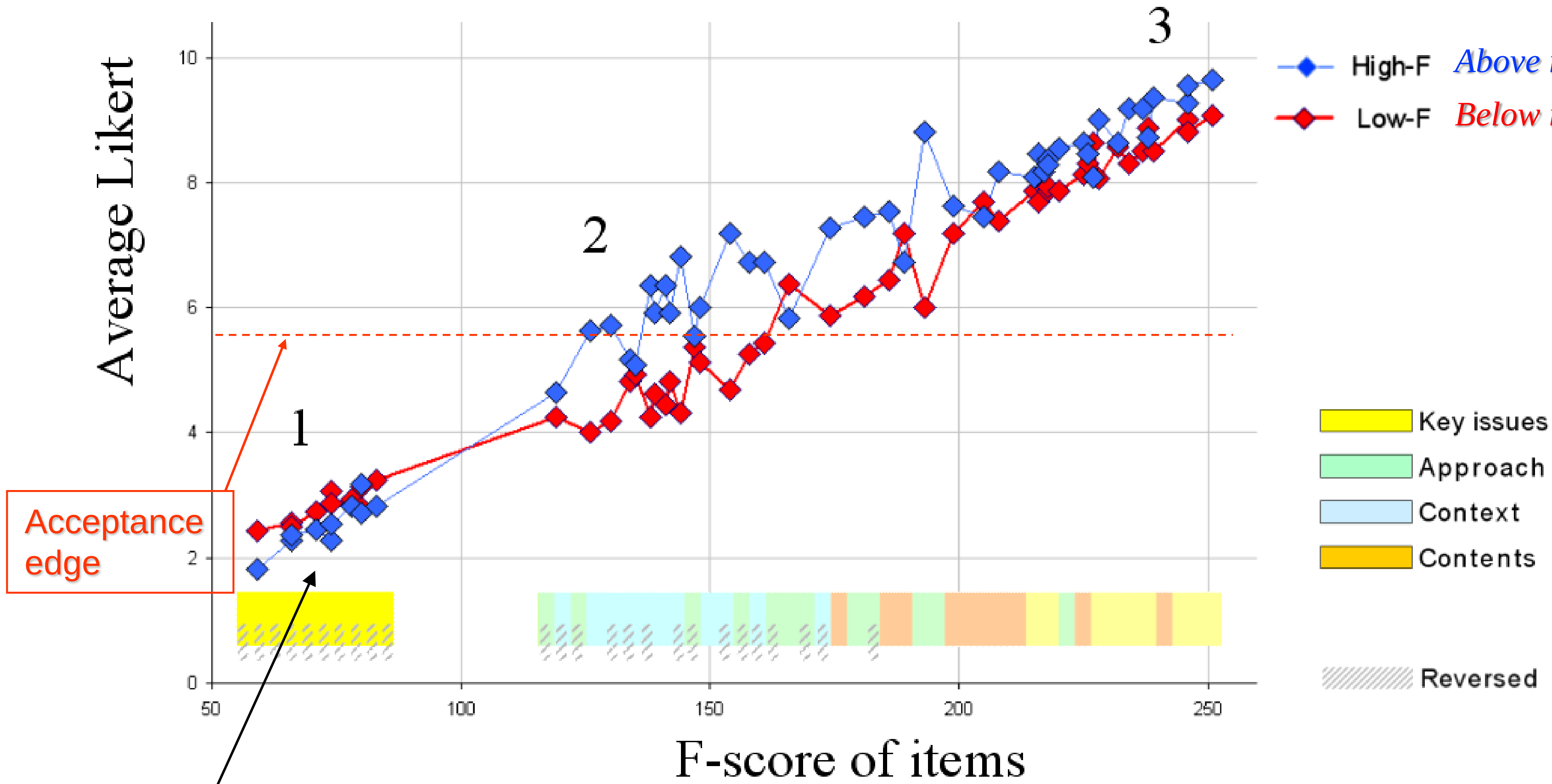
Key issues: coherent statements always earn a high grade

High acknowledgement of QMB key issues

Low discrimination between key issues of QMB and general issues of Physics

RQ#1 Results: *Teachers average Likert*

Marginal distribution #2



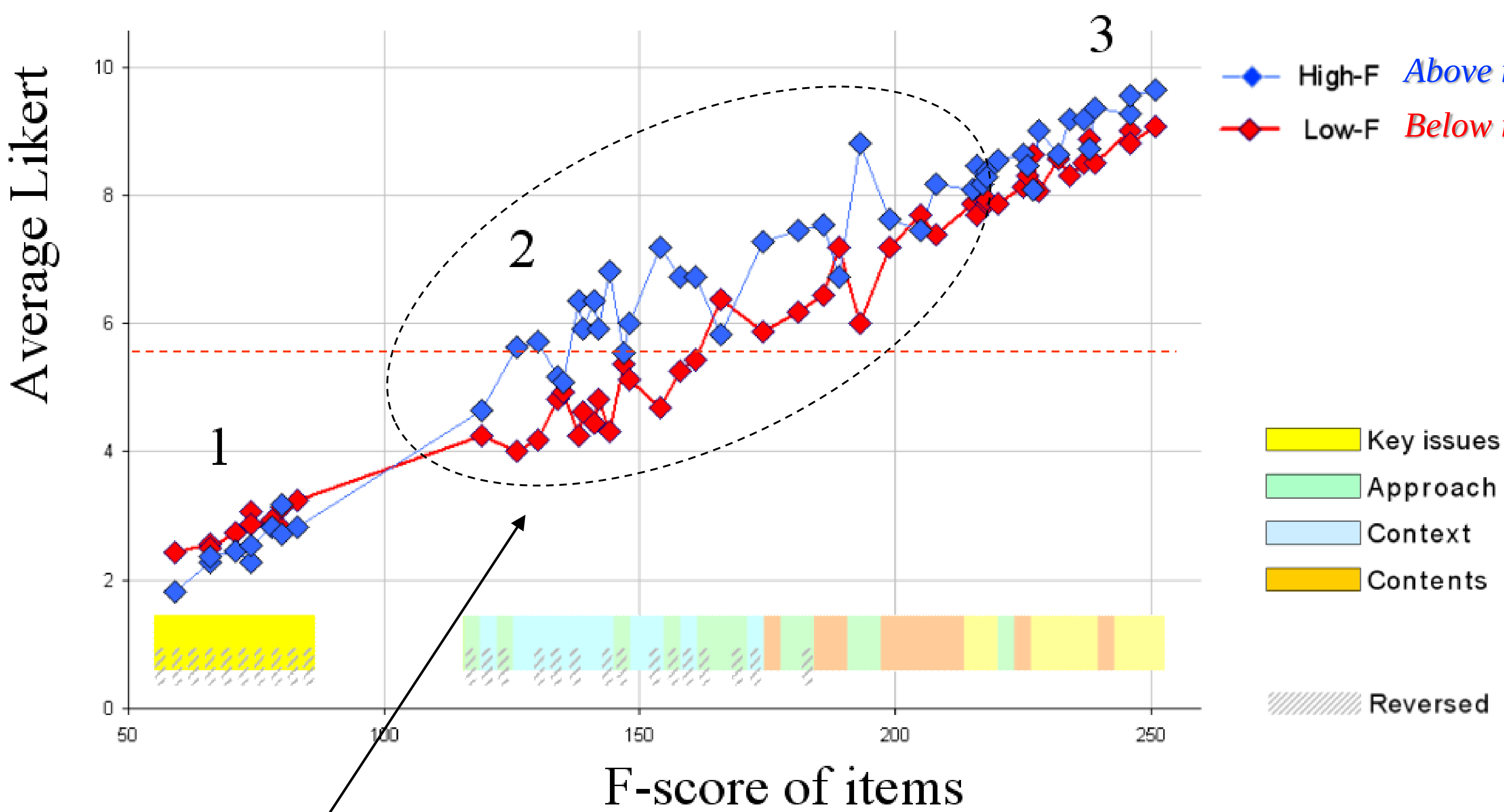
1. **Low L**
2. Scattered L
3. High L

Teachers are attracted by statements that make sense but are marginal by design in QMB.

- prepare a lab report with due care of **error propagation**
- introduce **high level math** to formalize QM problems
- **verify a theory** by experiment

RQ#1 Results: *Teachers average Likert*

Marginal distribution #2



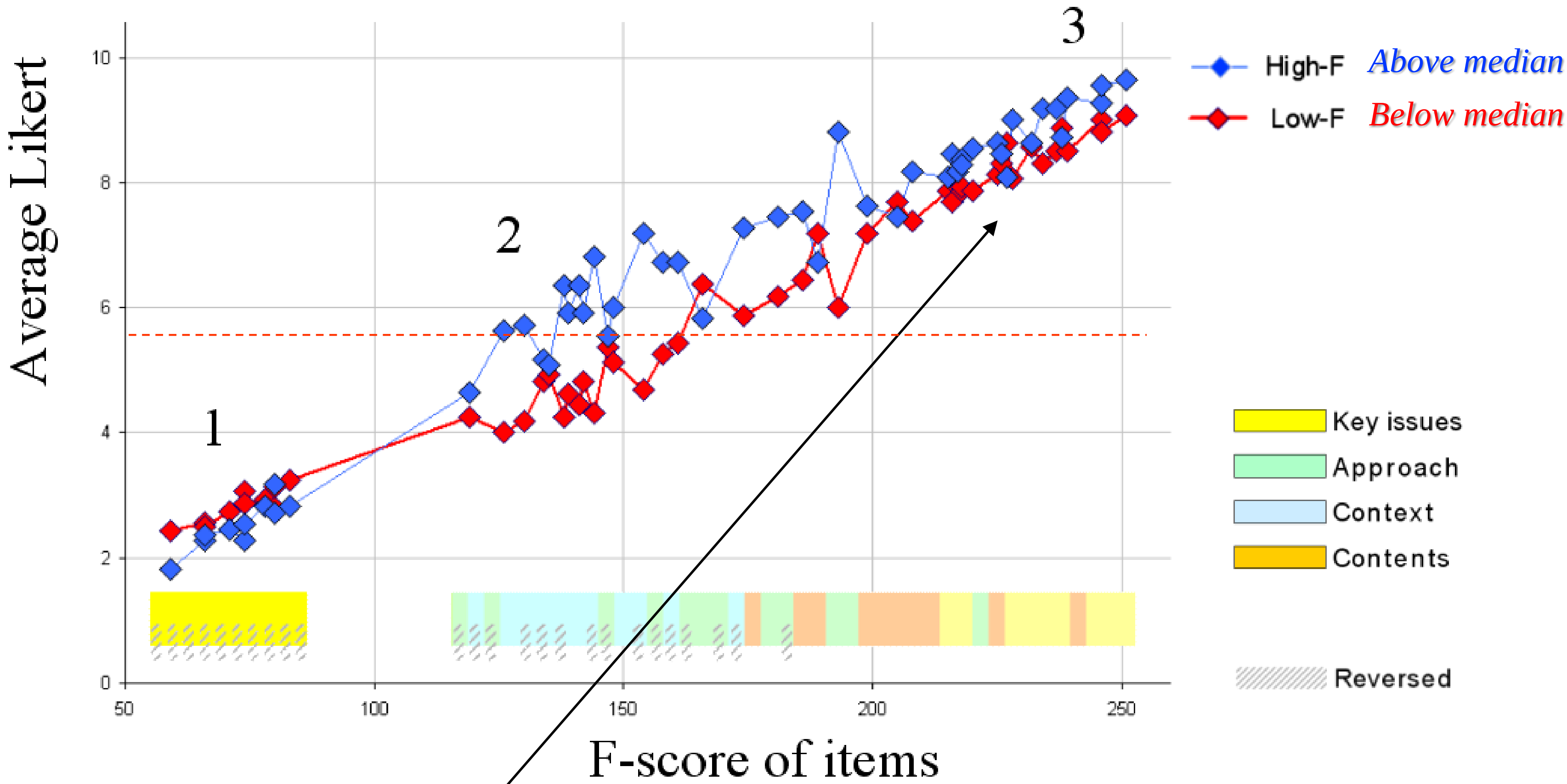
1. Low L
2. **Scattered L**
3. High L

<u>Some teachers are afraid that QMB may not fit the general scopes of the Physics curriculum and that students may fail:</u>

- It is difficult to introduce concepts such as **photon** and **action**
- I cannot renounce to the **historical approach** to QM
- A few **fundamental issues are missing**

RQ#1 Results: *Teachers average Likert*

Marginal distribution #2



1. Low L
2. Scattered L
3. **High L**

<u>Teachers agree on the true conceptual core of QMB</u>:

- The use of **representations**
- The role of the **lab** classes
- How to introduce the **limitations** of **Classical Physics**
- The relevance of **socioscientific issues**

RQ#2 Instruments: *interview with teachers on attitudes*

After classroom implementation

RQ#2 Results: *a case study*

"To what extent did you stress/ involve students on…"?

In the poll	In the interview	
Mathematical approach Historical approach	Lab approach Limitations of Classical Physics Socioscientific issues	**Key issues**
Wave behaviour of matter	Photon	**Contents**
QMB is far from my practise	Representations, etc.	**Approach**
QMB is difficult for my students		**Constext**

Her students performed **<u>very well</u>** in the final test!

The classroom implementation determined further **<u>shift towards QMB vision</u>**

Conclusions and Perspectives

RQ #1 What are the **teachers' perceptions** about QMB multidisciplinary approach?

Fidelity poll results

After the professional development course

Key issues & Contents

Teachers accept QMB key issues and contents, but conservatively don't single out them and show resistance to select and renounce to previous practices

Approach

Teachers mainly accept the QMB approach

Context

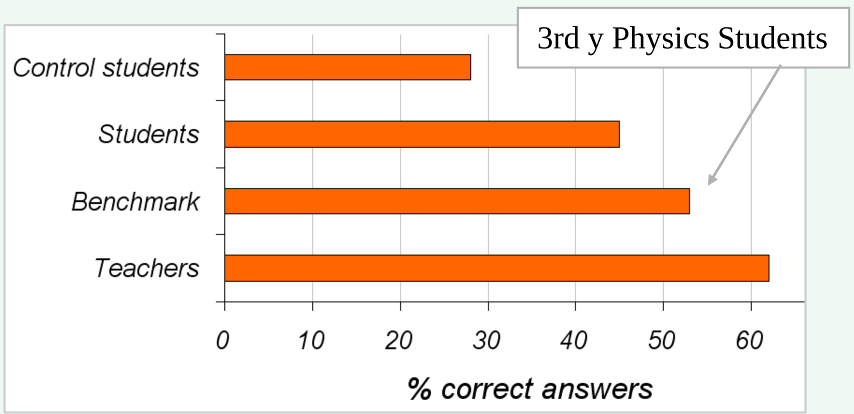
Part of the teachers are afraid that the QMB may not fit the general scopes of the Physics curriculum and that their students may fail

RQ #2 How far are they prone to **accept and actuate** the QMB core concepts?

QMB interviews

After classroom implementation

The interviews performed after the curricular implementation show further acceptance and positive inclination to actuate QMB



QMB final test

Next

- Full data analysis of teachers and students performances
- Deepening sequences: wave mechanics, qbits, entanglement