Can students design and execute their experiments in undergraduate practice courses?

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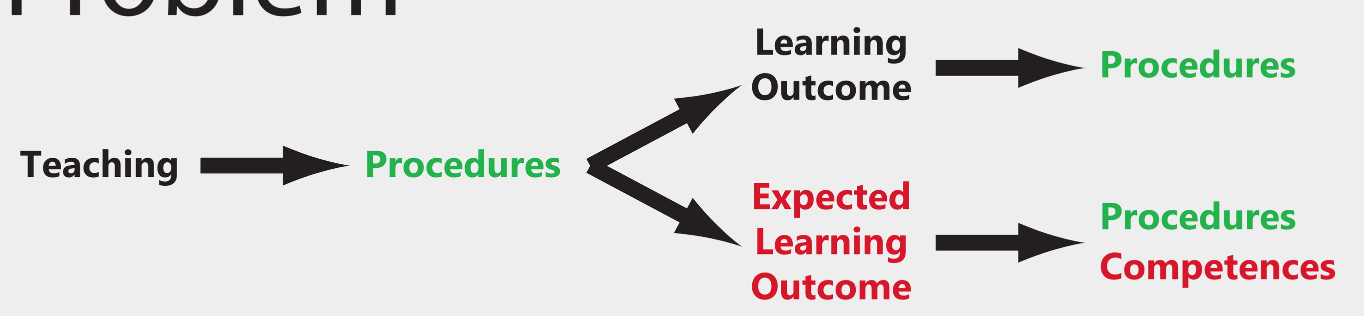
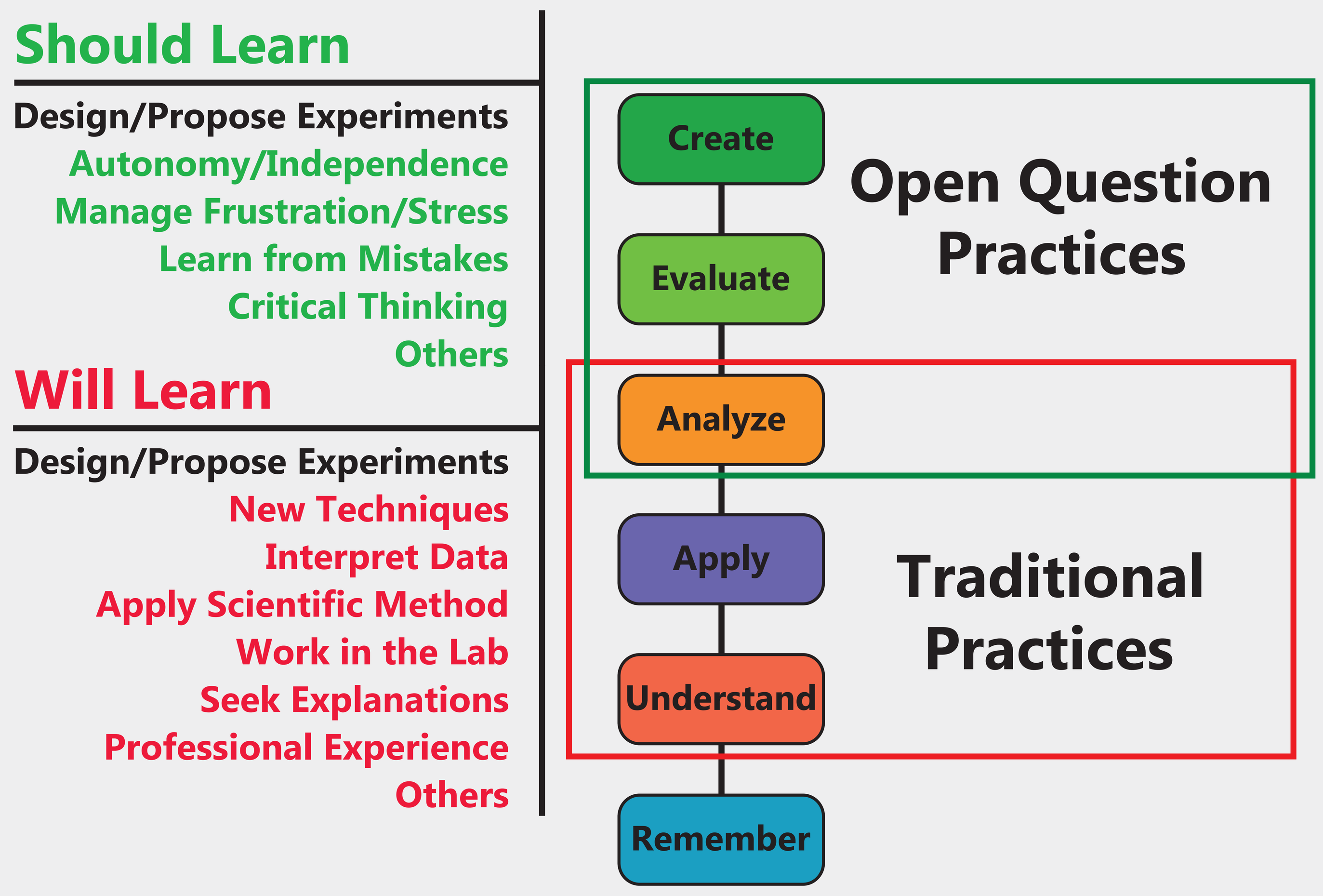
Problem



Adquisition of **scientific competencies**, i.e., capacity to solve questions through the scientific method, and **skills**, i.e., the ability to perform a protocol, are most commonly approached by practices. In general, practical courses are protocol based. Hence, students carry out one or several experiments following predetermined protocols, with very little or no freedom to decide how or which experiments should be performed to answer the proposed question.

Thus, if students are taught to follow procedures they acquire procedural skills, but not scientific competencies. To get those competencies they should be allowed to apply the scientific method to a given situation, get their own results and draw their own conclusions.

Rationale

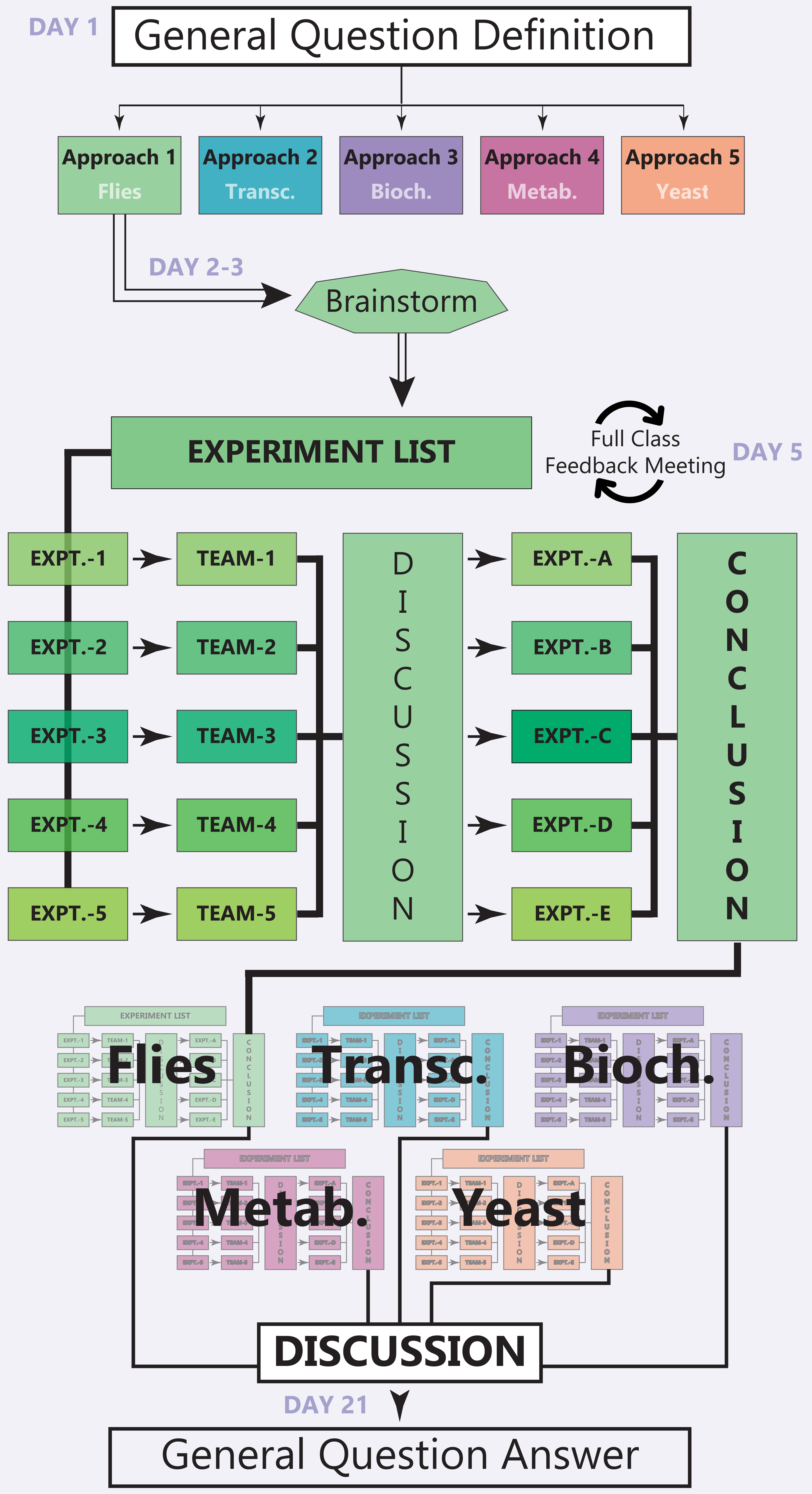


On the first day of the course, students (Biochemistry, 3rd year) are inquired about what they think they will learn versus what they should learn in a practical course. They anticipate their learning to be mostly procedural although their perception is that they should go far beyond acquiring technical skills.

Interestingly, **students expectations are in line with the competencies developed in open question practical setups**, which are in the upper levels of the Bloom's Taxonomy[1].

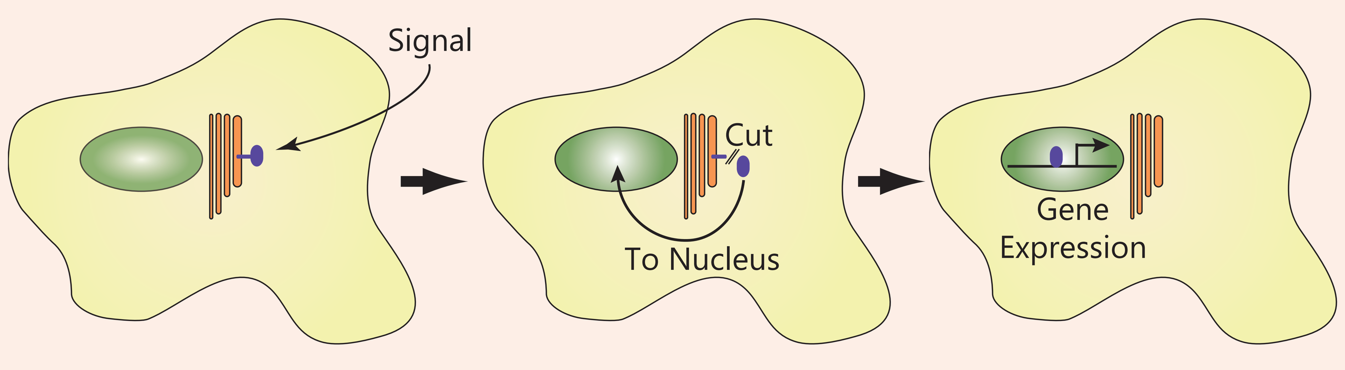
[1]Anderson LW et al. (2001) "A Taxonomy for Learning, Teaching, and Assessing: a Revision of Bloom's Taxonomy of Educational Objectives." Complete ed. Longman.

Teaching Approach



Model System

The SREBP pathway[1] was chosen as model to analyze. The pathway is well known, simple enough regarding the number of essential components and well conserved from yeast to mammals. The study was approached in two whole organism models, flies and yeast, and in insect cells from three different angles: Transcription regulation, including targets, and Metabolic and Biochemical regulation.



Evolutionary Conservation - Yeast to mammals

[1]Rawson R.B. Nat Rev Mol Cell Biol (PMID 12923525).

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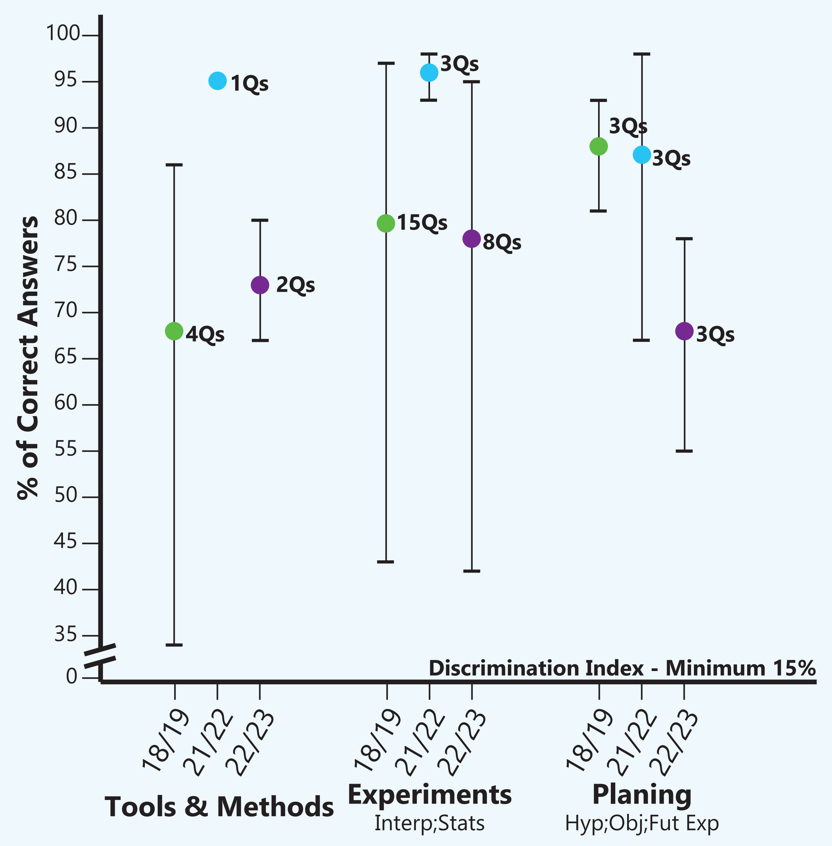
Learning Outcome

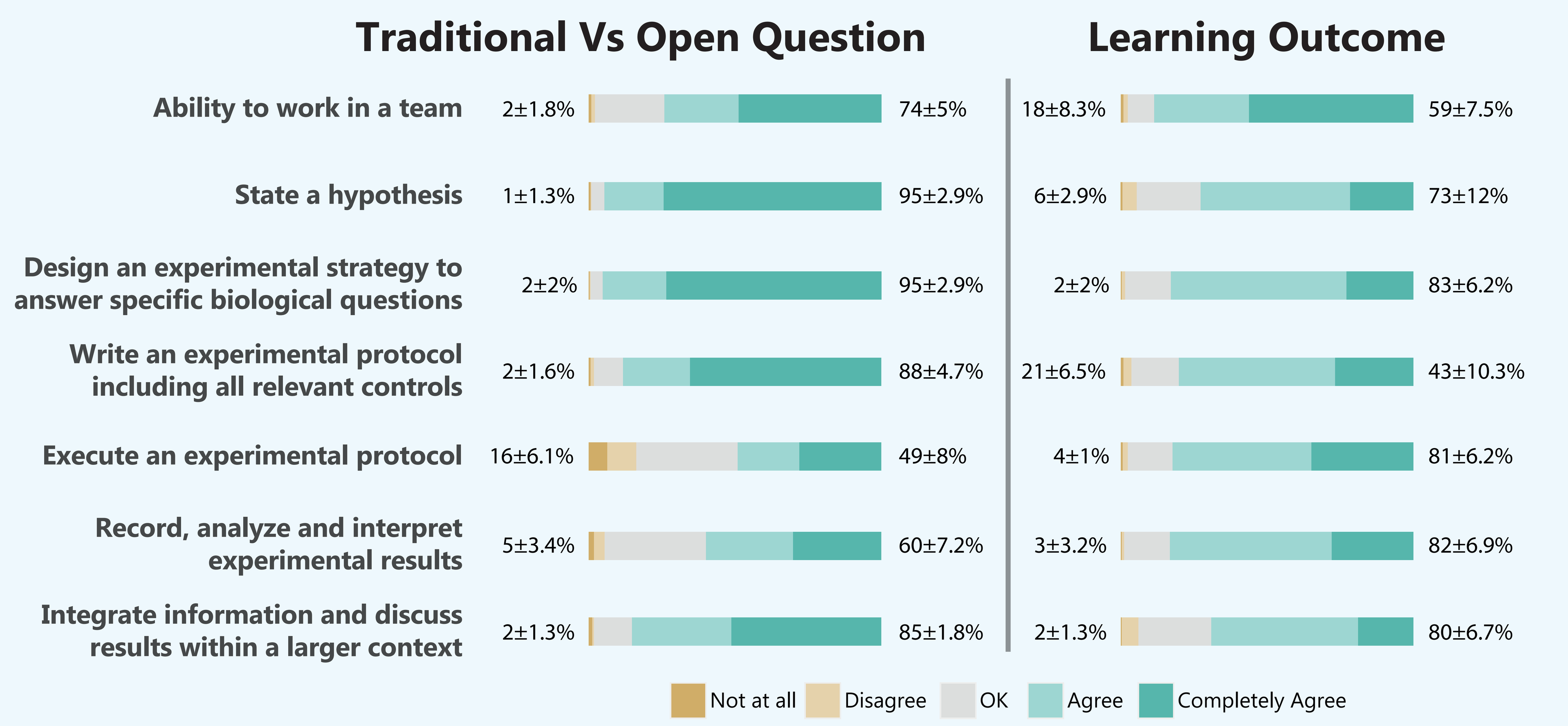


To examine student's learning results, exams' questions from three different years[1] were categorized and sorted into three groups, Tools and Methodology, Experiments (Interpretation and Statistics) and Planning (Hypothesis, Objectives and Future Experiments). Questions in each category were analyzed and those with either a Facility or a Discrimination Index[2] below 15% were discarded. Average Discrimination Index was 33%. The % of right answers and the number of questions for each category and year is shown. Bars indicate the questions with the highest and lowest % of right answers.

On average, at least 67% of the answers in each category and year were right. Furthermore, every single question but one was correctly answered by at least 42% of the students confirming effective learning in all three knowledge areas assessed.

[1]Number of Students: 18/19 – 58; 21/22 – 61; 22/23 – 55.
[2]Discrimination index: capacity of a question to differentiate between people with different levels of knowledge. Good items are recommended to have DI above 0.2. See: Kehoe, J. (1995). "Basic item analysis for multiple-choice tests". ED398237 ERIC/AE Digest. https://files.eric.ed.gov/fulltext/ED398237.pdf

Learning Perception



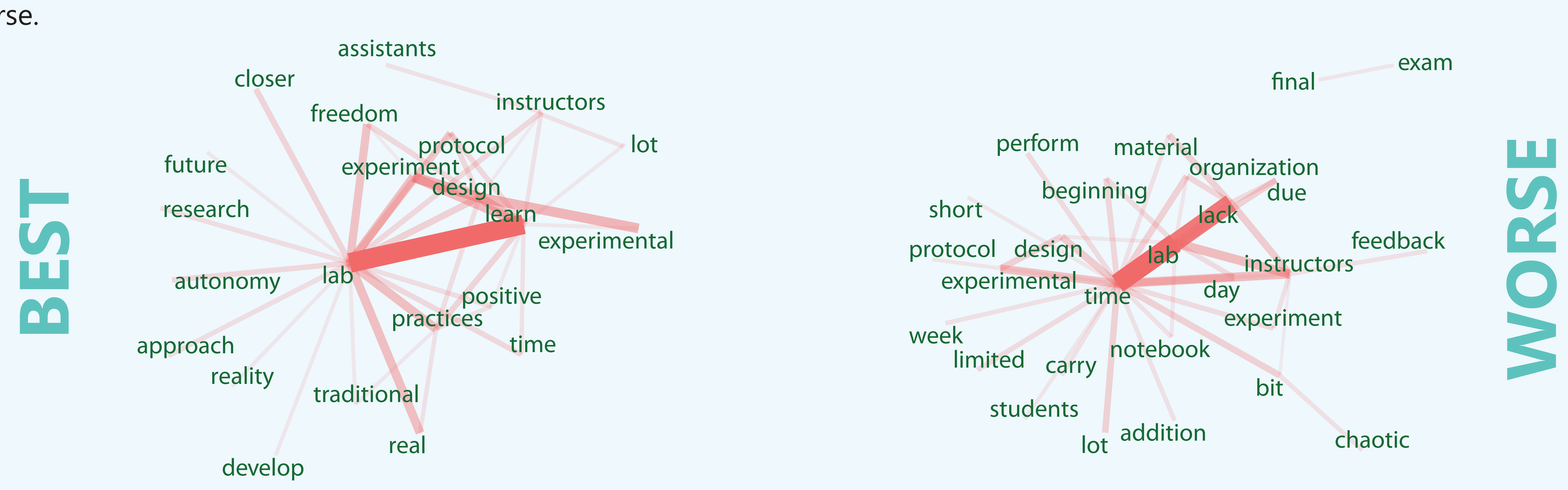
Each year, on the last day of the course, students are given a survey to express their opinions about the course, including the following sections: Methodology and learning objectives (see above), duration of activities, equipment, schedule, methodological objectives, interest, course evaluation, and the implementation of a MS OneNote electronic lab notebook.

Additionally, as shown below, free questions allow them to explain the best (left) or the worse (right) of the course.

Full Survey Results

Responses were plotted on a 1 to 5 Likert scale using the Likert R package and edited using Adobe Illustrator. The six-year average and standard deviation of negative (Not at all + Disagree) and positive (Agree + Completely Agree) responses are shown on the left and right of each bar, respectively.

Students appreciated the open-ended question method, with overall ≥50-70% positive responses for all competencies queried. In addition, as shown on the right, they felt that the approach was successful in learning the competencies.



Free-text questions were translated into English using DeepL and keywords were extracted using the R package akc. Co-occurrence of the 40 most frequent lemmatized names and verbs was then analyzed and displayed using udpipe package.

According to students, BEST aspects of the course are centered on laboratory work and research skills, including designing experiments and simulating a "real-world" context. However, although positively evaluated in the quantitative questions, they do not emphasize here that other important aspects such as teamwork or hypothesis generation were also strengthened.

On the other hand, lack of time and other constraints, such as organizational difficulties, are highlighted as WORSE facets.

Conclusions

1.- **Competencies and skill acquisition** is very effective and, most important for student's engagement and motivation, **learning perception** is very strong and positive.
2.- Open scientific questions **favor creativity** and enhance student's competence in experimental design and critical discussion of results.
3.- Open and flexible design of laboratory task allow students to become more responsible and improve student **autonomy and decision making** skills generating **high motivation and engagement**.

After several years, we can certainly conclude that an undergraduate practical course emulating a real scientific environment through an open question approach is a **viable option with big side benefits beside the intended learning outcomes**.