Innovative teaching approaches in applied plant sciences: experiences from European universities within the ESCAPAdE network

Julien Rose, Zbynek Polesny, Elsa Ballini, Marie-Stéphane Tixier, Dominique This

and the ESCAPAdE consortium

1. Introduction

Recent challenges in agriculture concern crop adaptation to climate change in relation to food security and related societal change in agriculture (agroecological perspectives, globalization, productivity and sustainability in agricultural and urban environments, the importance of plant health, resilience and adaptation to climate changes). Higher Educational Institutions (HEI) need to reflect these challenges in their curricula as well as in the innovative ways of teaching and learning. Although, the HEIs continuously maintain the role of the field of plant sciences in their curricula, including a range of disciplines with applications in crop management, including plant breeding and health, plant production, biodiversity protection, and ecosystem services. However they are facing a decline in the number of students considering plant science as a career option. It seems to be a reality at a time when there is a concern that future demand for plant scientists will very probably not be satisfied. The reasons for this decline are not obvious, but may be the result of a combination of student preference for animal science or medical-based degrees and a reduction of botany teaching at lower educational levels and a narrowing of plant-based university curricula at the undergraduate level. Innovative teaching/learning methods can broaden the learning opportunities for students and importantly engage students in applied plant sciences and research in general.

ESCAPAdE Erasmus+ project, conducted by a consortium of seven European higher education institutions in Life and Agricultural sciences, aimed to (i) develop pedagogical interactions between the scientists and teachers involved in Applied Plant Sciences

and (ii) apply them on a sample of European students originated from the partner universities. In August 2021 a summer school was organized to show that plant breeding and plant protection go side by side and that an integrated approach in plant sciences is needed to improve plant health. It gave the opportunity to 33 students from diverse origins, to exchange ideas on Applied Plant Sciences with people from different learning backgrounds and to experience the international and intercultural atmosphere associated with exchange programmes. This synopsis intends to provide some ideas and lessons learned from our experience.

2. What can attract students to study plant sciences

According to Dewey (1916), one prerequisite for learning is to generate enthusiasm around a topic and another to create linkages to prior experience. For example in agroecology, the decision case method has been used by many educators to meet these needs, but the majority of such cases are "closed" in that they present situations in which the solution is already known to instructor and client (American Society of Agronomy, 2006). Therefore in agroecology, the learning approach through open-ended cases was developed. The open-ended cases are distinct in their process of joint exploration by students, teachers, and stakeholders of complex real-life situations where often neither the relevant questions nor the answers have yet been identified (Francis et al., 2009). The open case method is further characterized by introducing students to a discovery approach to learning, to the need for digging out relevant information on a farm or in a community, to develop potential future scenarios rather than providing one discrete solution, and to elaborate a series of criteria for evaluating the success of the scenarios.

Another example could be botanical science. In the USA in 1996, educational institutions recognized the rapidly increasing educational trend characterized by teaching economic botany and ethnobotany. While there were few of such courses being taught, these courses had a greater depth and breadth of content, and attracted a greater diversity

of students, with more seeking general science, education, and social sciences, instead of primarily botany. The subsequent shift in focus from a strictly economic botany field was beginning to take shape as student interest broadened from general use of plants by people to cultural diversity and the cultural uses of plants, ethnoecology, and cultural conservation which gave rise to the field of Ethnobiology. The emerging field of ethnobiology education is positioned and ready to lead the way for change in the way students learn and in how they gain a better understanding of the nature of science.

In all cases, there is a real need to work on how to teach and train in order to improve knowledge transmission and skills development. This includes methods that involve learners, making them more active and enabling them to retain more information. It is also important to rediscover the pleasure of learning, teaching and training. The popularization and sharing of practices among education stakeholders is an essential point in promoting these pedagogical changes. With that objective, MAPe, a platform presenting innovative pedagogies from the practitioner side has been developed, as part of the "Asifood" Erasmus+ project, then adapted and implemented by ESCAPAdE partners in order to share their experience (https://www.supagro.fr/mape/?RecherchE&lang=en&facette=checkboxListeProject=02).

3. State of the art: some other examples of innovative pedagogies

3.1. Flipped Classroom (Inverting your class):

The Flipped Classroom Model basically involves **encouraging students to prepare for the lesson before class**. Thus, the class becomes a dynamic environment in which students elaborate on what they have already studied. Students prepare a topic at home so that the class the next day can be devoted to answering any questions they have about the topic. This allows students to go beyond their normal boundaries and explore their natural curiosity.

The tools you can use: Moodle, Google drive, Youtube, website, etc.

3.2. Design Thinking (Case Method):

This technique is based on resolving real-life cases through **group analysis, brainstorming, innovation and creative ideas**. Although "Design Thinking" is a structured method, in practice it can be quite messy as some cases may have no possible solution.

However, the Case Method prepares students for the real world and arouses their curiosity, analytical skills and creativity. This technique is often used in popular MBA or Masters classes to analyze real cases experienced by companies in the past.

Ewan McIntosh, an advocate of Design Thinking, created **The Design Thinking School** as part of his "No Tosh" consulting group. No Tosh harnesses the creative practices of some of the best media and tech companies in the world to coach teaching methods to implement the concept. Design Thinking for Educators also provides teachers with an online toolkit with instructions to explore Design Thinking in any classroom.

The tools you can use: Miro (Realtime board), etc.

3.3. Self-learning:

Curiosity is the main driver of learning. As a basic principle of learning, it makes little sense to force students to memorize large reams of text that they will either begrudgingly recall or instantly forget. The key is to let students focus on exploring an area which interests them and learn about it for themselves.

A perfect example of a teaching technique based on self-learning is outlined by **[Sugata Mitra at the TED conference](#)**. In a series of experiments in New Delhi, South Africa and Italy, the educational researcher Sugata Mitra gave children self-supervised access to the web. The results obtained could revolutionize how we think about teaching. The children, who until then did not even know what the internet was, were capable of training themselves in multiple subjects with unexpected ease.

A common technique for exploring self-learning is the use of **Mind Maps**. Teachers can create a central node on a Mind Map and **allow students the freedom to expand and develop ideas**. For example, if the focus is the Human Body, some students may create Mind Maps on the organs, Bones or Diseases that affect the human body. Later the students would be evaluated according to the Mind Maps they have created and could collaborate with each other to improve each others Mind Maps and come to a more comprehensive understanding of the Human Body.

The tools you can use: Mindmeister, Genial.ly, Knightlab, Padlet, etc.

> https://www.supagro.fr/mape/?CollaborativeMindMap&lang=en

3.4. Gamification:

Learning through the use of games is one of the teaching methods that has already been explored especially in elementary and preschool education. By using games, students learn without even realizing. Therefore, **learning through play** or '*Gamification*' is a learning technique that can be very effective at any age. It is also a very useful technique to keep students motivated.

The teacher should design projects that are appropriate for their students, taking into account their age and knowledge, while making them attractive enough to provide extra motivation. One idea may be to encourage students to **create quizzes online** on a certain topic. Students can challenge their peers to test themselves and see who gets a higher score. In this way, students can enjoy the competition with peers while also having fun and learning.

The tools you can use: Escape Game, Serious Game, Kahoot, Padlet, etc.

3.5. Social Media:

A variant of the previous section is to utilize **social media in the classroom**. Students today are always connected to their social network and so **will need little motivation** to get them engaged with social media in the classroom. The ways you can use teaching methods are quite varied as there are hundreds of social networks and possibilities.

A good example is the initiative carried out by the Brazilian Academy of Languages "Red Ballon", which encouraged students to review the tweets of their favorite artists and correct grammatical errors that they committed in an effort to improve their English language skills!

<u>The tools you can use:</u> Twitter, Instagram, Facebook, etc.

Example: https://www.edutopia.org/blog/guidebook-social-media-in-classroom-vicki-davis

3.6. Free Online Learning Tools:

There is an array of free online learning tools available which teachers can use to encourage engagement, participation and a sense of fun into the classroom. Teachers can create an interactive and dynamic classroom environment using, for example, online quizzes to test student's knowledge.

<u>The tools you can use:</u> Miro (RealTime Board), Padlet, Wikis, Genial.ly, Knightlab, Canva, Moovly, etc.

3.7. Additional Techniques to create pedagogical resources

As communities and technologies constantly evolve, so must teaching practices. Below is an extensive list of popular teaching strategies that have been incorporated into courses nationwide. These methods break tradition and challenge students to think critically, collaboratively, and creatively.

A list from SaintXavier University (Chicago) : https://www.sxu.edu/academics/resources/cidat/faculty-toolkit/pedagogical-resources.asp

3.88. Pedagogical methods from MAPe

- · Barcamp

A Bar Camp is an open "non-conference" that takes the form of participatory workshops-events where the content is provided by the participants who must all, in one capacity or another, bring something to the Barcamp, the objective is above all to share ideas.

Presentations by learners of several topics around a central theme to small groups of learners.

- Ø https://www.supagro.fr/mape/?BarcamP2&lang=en

- Ø https://www.supagro.fr/mape/?EducationalSystemAroundTheBarcamp&lang=en

- · Pedagogy by project

Pedaggogy by project aims to develop practical skills with learners, to initiate in them the spirit of a project developer, and put autonomy in work a central value to transmit to them.

Ø https://www.supagro.fr/mape/?PedagogyByProject&lang=en

· The 20 minutes

A person's attention inevitably drops after 20 minutes. During an intervention that lasts more than 20 minutes, the objective is, through an animation (video, story, poll...), to break the rhythm of the session in order to regain the audience's attention.

Ø https://www.supagro.fr/mape/?The20Minutes&lang=en

· The Graduated Method

Following a course already given, some key points can be identified as barriers to understanding and learning. The aim of the progressive method is to return to these points during a TD by proposing one or more activities to the learners.

The activity is done initially in pairs then in small groups then possibly in larger groups.

Ø https://www.supagro.fr/mape/?TheGraduatedMethod&lang=en

· World coffee

It is a dynamic group work where different workshops are proposed. It mobilizes the qualities of expression (oral and written) and creativity of the participants.

Ø https://www.supagro.fr/mape/?WorldCoffee&lang=en

4. Students' perception on innovative pedagogies

The ESCAPAdE consortium conducted a small survey on the perception of innovative pedagogies by our students, based on their own experience and ideas. This represents useful data to take into account before developing new ones.

Two separate online surveys, prepared through framaform (https://framaforms.org/) were sent to students from the seven university partners of ESCAPAdE in 2019, with some questions not overlapping to each other's. They have been merged manually, but then for some missing questions the answer was arbitrary indicated as "no opinion" or "I don't know".

Detailed results can be found at http://escapade-erasmus.eu/results/special-web-plateform/ .

Very few students had experienced the last three ones during their curriculum. However,

problem-based and mastery-based learning were the most appreciated activities.

Mastery-based, discussion-based and problem-based approaches were considered to be well adapted to improving general knowledge in Plant Sciences for Agriculture, whereas some students considered that mastery-based approaches are not useful. Computational-based approaches were relatively well appreciated, but flipped learning and game-based approaches were generally appreciated with this objective.

After the question "Do you remember the scientific subject learned with this new pedagogy?", 60% of the respondents indicated that they remembered the subject learned, which is quite a good score.

Students who experienced innovative learning activities also believed that their learning success was higher. They would prefer the proportion of innovative pedagogies to be increased. But the quality of those pedagogies mostly depend on teachers who are providing them, indicating teacher's need of support when developing new pedagogical methods.

According to students answering the survey, the main advantages of innovative pedagogies were:

"It improves student's engagement"

"It improves student's self-discovery"

"It improves imagination and creativity"

"It improves transfer of understanding"

"It improves relevance to real life"

However, the students were less convinced that "it improves know-how and craftmanship".

The main drawbacks identified were:

"Some students are left behind"

"It takes too much time"

"Mostly not well prepared"

These comments again underline teacher's need for support when planning and applying new pedagogical methods.

Three types of learning organization were proposed:

- Cooperative learning (students working as a team to maximize their own and each other's learning with some level of interdependency)

- Collaborative learning (students progressing individually towards a common goal while being individually and collectively accountable for their works)
- Autonomous learning (individual take responsibility for their learning.

Collaborative learning was preferred, followed by cooperative and autonomous learning, but no clear tendency was observed. All three types of learning should certainly be maintained to promote individual learning as well as adaptation to teamwork.

5. Contribution of ESCAPAdE partners to innovative pedagogies through their experience

Fourteen "cards" have been written by ESCAPAdE partners during the time course of the project, based on their previous experience:

- Active learning: the example of using a simulator
- BarCamp
- Changed Roles
- Educational system around the BarCamp
- Journal Club based learning
- Learning by doing: The example of a board game
- MOOC NECTAR : A Flip-Flap Massive Open Online Course on Arthropod and Nematod management for crop protection
- ONLINE Seminars with Top Researchers
- Project-based learning in applied plant sciences (ESCAPAdE project)
- Simulation of a real project: notifications concerning releases of genetically modified higher plants
- The Flipped Classroom
- Interactive and online Jigsaw group activities
- Students' debate
- Teaching tip: the Postcards activity

6. Summer school: the environment for testing innovative teaching methods

The categories of currently used teaching methods include traditional lectures, interactive class discussions/debates, secondary research on published research papers, primary research, inquiry-driven learning based on student questions, case studies/scenarios in the classroom, model-based learning of complex concepts, student

portfolios, reflections, journals, blogs/websites, problem-based learning where student groups work towards a solution, team-based learning through structured tasks, among others.

Escapade project during the summer school *Host Plant Resistance Breeding as a part of Integrated Pest Management* tested some of the recent innovative teaching/learning methods to show techniques related to plant breeding and protection such as gene pyramiding, genomic selection, genetic modification, genome editing, and application of biologicals, together with concepts of multivariate and intercropping systems in an agro-ecological perspective. The importance of readily available genetic materials in biobanks and legislation as well as public perception and acceptance of innovations were also discussed. The teaching was complemented with a case study-based exercise in relation to crop protection, tutored by young researchers (phD or postdocs) and benefiting from the supervision of professionals. .

The summer school course was based on project-based learning (PBL) complemented with lectures, study visits and literature surveys. The lectures were designed using methods like Flipped Classroom, Jigsaw Collaborative Discussion Method, among others.

This table presents the types of pedagogies that were used during this summer school, with their reference in MAPe platform when available.

Type of pedagogy	Description of the task for students	Teachers in charge during ESCAPAdE	Reference in MAPe

		summer school	
Self-presentation	Create a self-presentation on Padlet	Erik Alexandersson (SLU)	
Board game on host resistance	To discuss plant immune system with the help of a game	Elsa Ballini (MSA)	https://www.supagro.fr/mape/?LearningByDoingTheExampleOfABoardGame&lang=en
Computer simulation	Use the R package "landsepi" to find an optimal strategy to deploy major gene resistance	Loup Rimbaud (INRAE/ MSA)	https://www.supagro.fr/mape/?ActiveLearningTheExampleOfUsingASimulat&lang=en
Student debate	Learn about decisions on the approval and usage of pesticides from different points of view	Björn Klatt (Lund University)	https://www.supagro.fr/mape/?StudentsDebate&lang=en

Discussion-based teaching	Discussion: How do you plan for Microbe assisted breeding for your favorite crops? (Preceded by an introductory video)	Soledad Sacristan (UPM), Ramesh Vetukuri (SLU)	
Flipped classroom	Each of four groups prepares a short (~20 minutes) teaching unit - using a presentation tool of your own choice- on one of four topics: 1) resistance breeding with phenotypic selection; 2) resistance breeding using marker- and/or genomics assisted selection; 3) breeding for pest- and/or disease resistance using transgenics; 4) new breeding technologies for resistance breeding	Elena Benavente, (UPM), David Collinge (UCPH), Hermann Bürstmayr (BOKU), Sjur Sandgrind (SLU), Laura Morales (BOKU)	https://www.supagro.fr/mape/?TheFlippedClassroom&lang=en
Interactive and online Jigsaw group activities	Group discussions in a jigsaw formation on how to breed for disease resistance in newly domesticated/orphan crops	Cecilia Hammenhag (SLU), Zbynek Polesny (CULS)	https://www.supagro.fr/mape/?InteractiveAndOnlineJigsawGroupActivities&lang=en

Project-based learning	Students divided in 8 groups (identified by a logo on a bandana and a badge) try to solve an existing challenge for plant research.	PhD / postdoc tutors, non-academic advisors, academic supervisors (Dominique This, Julien Rose (Institut Agro), David Collinge (Copenhagen U).	https://www.supagro.fr/mape/?ProjectBasedLearningInAppliedPlantScience&lang=en
Students' feedback on a postcard	Students write their best memories of the summer school and lessons they will bring back home on a postcard, sent two months later with an illustration from the summer school	Julien Rose, Mathilde Cathelain (Institut Agro)	https://www.supagro.fr/mape/?TeachingTipThePostcardsActivity&lang=en

The course was ethically grounded. The ethical standards for research including general research ethics as well as international agreements such as Nagoya Protocol and International Treaty on Plant Genetic Resources for Food and Agriculture were followed.

The students were evaluated based on their active participation, approved written logbooks based on the different parts of the course including a reflection on the pedagogical tools used, and oral presentation of the case study.

One aspect which can attract more students to the field of applied plant sciences is also their involvement in different professional platforms and scientific societies. Many of the societies (e.g. Society for Economic Botany,…) have students' sections that provide important feedback to the society and on the other hand, students benefit from this membership having close contact with researchers at the international level, receive

information on internships, fellowships, research funding opportunities and planned conferences. Therefore the summer school was followed by a Job Fair, co-organized with plantLink which invited around 100 international students, researchers, and project stakeholders for networking. Information on this jobfair and some,invited presentations can be found in https://www.plantlink.se/registration-to-the-plantlink-and-escapade-jobfair-23-24-of-august-2021/

7. Learning outcomes

Learning outcomes are another central feature of every teaching activity, which is in line with the new emphasis on twenty-first-century strategies for students. Learning outcomes describe what the students should be able to do or know. They encompass the core concepts and competencies for applied plant sciences education.

In our case, the summer school aimed to show that plant breeding and plant health go hand in hand and that a broad approach within plant science is needed to improve plant health. In addition, it was highlighted that more research was needed for agriculture and forestry to become more sustainable and help reach the Sustainable Development Goals (SDGs) set in Agenda 2030.

Within the core concepts, the students after completing the course should be able to: (1) understand the connection between resistance breeding and plant health, (2) describe some methods related to resistance breeding of crop plants, (3) have insight on the need of collaboration and communication between the society, academia, and breeding and protection companies to reach UN Sustainable Development Goals.

Such objectives are part of a larger core of learning outcomes that all students preparing a degree in Applied Plant Sciences should have. However, no clear definition of learning outcomes defining a "quality standard" MSc degree in Applied Plant Sciences is

available to our knowledge. Therefore, one of the tasks of the ESCAPAdE project was to define general and specific learning outcomes at the MSC level that would be consensual fro European universities, and prepare procedures and standards for a quality assurance label in Applied Plant Sciences. The main objective of this label would be to facilitate recognition of specific qualifications within the European Higher Education Area and with other education systems, and to provide the ground to raise the quality of programme degrees within the Applied Plant Sciences area. It has been discussed as brainstorming sessions within the network and amended after a self-assessment test conducted on a MSc programme in SLU (Sweden). In addition to standards and guidelines for internal quality assurance, we propose to include subject specific criteria, divided into five broad subjects:

- genetic resources and plant breeding

- plant health

- plant production

- methodological skills

- soft skills

The learning outcomes defined by the project can be found at http://escapade-erasmus.eu/results/mobility-search-tool/

8. Discussion on. Innovative teaching approaches tested during the summer school.

8.1.1 Project-Based Learning

Project-based learning developed during the ESCAPAdE summer school is based on Project-based Learning within a course entitled "Designing New Crops for the Future", open to Montpellier SupAgro Master 1 students and Erasmus students. The project includes some scientific knowledge that the student needs to understand, learn, assimilate and reuse. Moreover, it includes a specific problem to be solved through careful planning and project execution. Personal and group guidance is applied to solve any challenges arising during the project.

The main goals to be achieved are: (1) apply scientific concepts, (2) develop ability to work as a multicultural or international group, (3) benefit from multidisciplinary knowledge shared within the group, (4) enhance motivation in a positive competition, (5) exchange ideas and a scientific approach with young researcher, (6) produce a result of potential interest for professionals, (7) produce a result of potential interest for professionals, (8) communicate in front of a professional and academic panel.

The teaching sequence, originally conceived over four weeks, was adapted to one week, each day presenting a different item, moving the project forward. In our case: (1)Discover the group/tutor and the subject, online, before Summer school, (2) Launch of PBL: group meeting and discussion of context with tutors (Mind mapping of project context), (3) Brainstorming on project's solution to be developed, (4) Project development (Data collection, draft for project oral / written presentation, (5) Presentation rehearsal , (6) Project presentation in 180 seconds to academic and non-university advisors, (7) Awards ceremony.

Each project was supported by a young researcher (PhD or postdoc), with the help of an advisory professional, and piloted by academic staff. Topics of projects conducted during this course were: (1) Breeding/phenotyping for Spider mite resistance, (2) Alternaria resistance inquinoa, (3) Virus yellows in sugar beet (4) Testing of essential oils and their vapors against pathogens, (5) Domesticating Moringa, (6) Resistance breeding for bunt resistance in wheat, (7) Genomic selection and large scale data in cereals, (8) Insect pests: interactions with fruit crops.

Volunteer young researchers had to be identified well in advance, as well as non-academic (professional-) advisers, working in their companies on similar project or on the same crop. All tutors were assigned a group of 4 students from different origins. . to be prepared in advance for this particular teaching activity, since this was a very new teaching experience for all of them. During a two-hour online meeting, the process of project-based

learning was presented, and a proper attitude was discussed with them to avoid over-mentoring or over-specified projects. Specific learning material (on-line resources and a summary of the project) was prepared and shared through Canvas with students. Despite the availability of this material, very few students read the material in advance.

A large autonomy was given to the tutors to conduct the PBL during the week. All of them were able to share their enthusiasm about their research project and the final presentation by students showed their ability to embrace a new subject and provide some new ideas to solve the scientific questions in a very professional way. Probably however a longer period (at least four weeks?) would be necessary for them to go deeper into their projects. In any case, the feedback of tutors in this exercise was very positive (you may find some interviews at https://escapade-erasmus.eu/presentation/stories-of-innovation-and-mobility/). Therefore this exercice had multiple outcomes of (i) training MSc students to some fronts of Applied Plant Science, (2) letting them discuss with phD students on possible future path for them, and for PhD students to get trained to interactive teaching.

4.2 Jigsaw Collaborative Discussion Method

"Jigsaw classroom" is a teaching technique invented in 1971 by the American social psychologist Elliot Aronson.

It uses a cooperative learning strategy that strongly encourages students to listen, engage, interact, share and thus gives everyone a key role to play in the academic activity.

The primary strategy of this method is to create assignments and activities that allow students to cultivate topic-specific expertise and then teach the material they have learned to other students in the class. Student groups are then asked to draw on everyone's expertise to complete a task together or prepare for an individual exam.

In its simplest version, an instructor can form groups A, B, and C and assign each group a different reading or lab skill to learn. These are called "expert" groups. Once each

student group has mastered the required content or skill, the instructor then forms new groups with one student from A, B, and C in each group. These are called "home" or "jigsaw" groups. Those students are now "experts" in the material they learned in their original groups, and they can teach students in the homegroup what they have learned.

In our case, we developed the 2-hour module on the topic "Best breeding strategy towards resistance breeding for a crop under domestication - the field cress (*Lepidium campestre*)" case. The module was divided into 4 subtopics: (1) Natural variation, (2) Marker-assisted selection & genomic predictions, (3) Transgenic resistance, and (4) New breeding technologies. For each subtopic, the set of learning materials including research papers, instructional videos and links to databases were provided via the Padlet platform.

The module started with an explanation of the task complemented with a mini lecture on field cress domestication. First, students were asked to learn about the plant species, especially (1) What has been done so far?, (2) What is available?, (3) What needs to be developed?, (4) What is the main challenge of your subtopic's approach?

4.2 Flipped Classroom

Flipped classroom has been used to teach students about different breeding methods for resistance: 1) resistance breeding with phenotypic selection; 2) resistance breeding using marker- and/or genomics assisted selection; 3) breeding for pest- and/or disease resistance using transgenics; 4) new breeding technologies for resistance breeding

Students were separated into four groups of 8 students and had to learn and understand online material (mainly reviews) related to one of those four topics before the start of the summer school. Contact between students and teachers were done through Canvas, but they didn't know each others before the start of the meeting.

During the first days of the summer school, teachers and students met in order to raise a few issues. Teachers were then able to answer to student's questions. During the course, students were then asked to present their part to students from the other groups through different ways, depending on their group decision. It could be done through regular lectures, game roles, discussion-based teaching… Some students even interviewed specialists and presented a video. All student's lectures were sound and revealed the good preparation of students and their ability to present a science topic in a collaborative way within the group. Students appreciated this way of learning, they learned a lot on their specific project and appreciated their interaction with teachers. However, peers' understanding of the lecture could not be evaluated properly due to a lack of time.

4.3 Board Game: Host Resistance

 Fall of Plant Castle is an educational game created by Elsa Ballini, based on "Learning by doing", which allows students to understand plant immunity and the different molecular actors involved in the recognition of a pathogen by the plant. Largely inspired by the game "Vegevaders" (https://blogs.cornell.edu/cibt/labs-activities/labs/vegevaders/), it offers players the opportunity to become familiar with the molecular mechanisms in one hand used by the plant to recognize a pathogen and defend the plant cell and in the other hand used by the bacteria to suppress plant defense and attack the plant cell.

The game presents two different components of bacteria: MAMP (Microbe Associated Molecular Pattern) that are a general pattern present in microbes and effectors that are small molecules secreted by pathogens to attack plants. The game also presents three different components of the plant immune system : MAMP receptor, plant defense and resistance genes. One player will have to simulate the attack of a bacterium on the plant, and the other will have to use the defence mechanisms of the latter. The aim is also to highlight the selection pressures that are exerted on these different proteins and thus explain the appearance of new pathogenic variants.

Thus the first objective of this game is to check student knowledge on the plant immune system. They can directly experiment which are the molecular components required for example for the plant to trigger an hypersensitive response and thus reproduce the gene for gene theory that is a key knowledge sometimes difficult to acquire. This game can ideally be used after a flipped classroom to validate what has been learned during the online assignments. The students will better integrate the different aspects of plant immunity. In the session, the students will be able to exchange and coordinate with each other thanks to the board game on the immune plant system. Some students that may not have acquired the different knowledge will better understand by "peer learning". This step is particularly important to ensure that the whole group starts with the same knowledge.

As an interactive resource this game also allows discussion on disease control strategies: how to induce plant immunity using a plant resistance inducers? How a pathogen can overcome plant resistance? Which plant ideotype will allow the more durable resistance? Students will thus be coach to move to new learnings on plant resistance inducers, plant breeding for resistance, plant resistance management. In particular it can be interesting to use the epidemiological model landsepi (see below) in a second step to further investigate plant/pathogen evolution and plant resistance durability. The objective of the discussions is to play with the rules and to adapt the rules in order to understand the consequences of a particular strategy on plant immunity and pathogen evolution. Students can thus experiment and create a variety and discuss the consequence of this ideotype construction.

At the summer school in Sweden, this activity was used in a flipped classroom. Students were asked to watch online videos before the lesson to update their knowledge of plant immune systems. Three videos were used produced by iBiology, SainsburyLab and CultiVar project. They provide insights into the introduction of plant-pathogen interactions, plant immunity and finally sustainable management of disease resistance in plants.

4.4 Modeling Approach using Landsepi: Landscape Epidemiology and Evolution Model

The landespi simulation provides a general modelling framework to help compare plant resistance deployment strategies and understand the impact of epidemiological, evolutionary and genetic factors for a wide range of pathosystems. Strategies to improve plant resistance management rely on careful selection of resistance sources and their combination at various spatio-temporal scales. Different cultivar deployment strategies can be proposed : pyramiding, mixture, mosaic and rotation that have been previously described to increase resistance durability (https://onlinelibrary.wiley.com/doi/full/10.1111/eva.12681). In landsepi simulation, the landscape is a dynamic mosaic of fields cultivated with croptypes. Each croptype is composed of either a pure cultivar or a mixture; and each cultivar may carry one or several resistance genes. Each resistance gene targets one or several pathogenicity traits, with complete or partial efficiency. The pathogen may adapt to these genes (restoring its pathogenicity), possibly associated with a fitness cost. The model accounts for pathogen evolution (via mutation, sexual reproduction, selection and drift) and provides epidemiological, evolutionary and economic outputs to assess the performance of the simulated strategies. The simulation is based on a R package but the simulation here uses a shiny interface for pedagogical purposes.

Students can test different hypotheses and different strategies and will see the consequences of their choice after 10 or 30 years of pathogen evolution. They can evaluate consequences of annual epidemic loss but also consequences on resistance durability. They have to test different strategies in oder to find the most suitable to avoid resistance overcome. So they can modify different parameters to test their hypotheses (landscape aggregation, number of resistance genes, proportion of resistant varieties). This simulation is particularly interesting to allow students to learn by testing and by errors.

During alnarp Summer school this simulation was used inside a course of Loup Rimbaud on the management of plant resistance. He could alternate between a question to students that

required to make an hypothesis and to test it with the simulation and then a transmissive course to answer the question. This allows students to be more active during the course by alternating lecture and practical phases. It also allows the course to be broken down into 15-minute phases that keep the students' attention. This type of active learning is particularly appreciated by students to allow a better understand of the different knowledges.

4.5 Student debate "The rise and fall of neonicotinoids"
 Historically, the practice of debate is linked, on the Greek agora, to the emergence of democracy. Later, the philosophy of the Enlightenment established a close link between the birth of the modern democratic state and the existence of a public space ensuring the right of expression and confrontation of opinions.

"Knowing how to debate" is a key skill in civic education, a way for learners to experience, in a situation and in the institution, a public and responsible speech. Debating implies a communication ethic without which one falls into physical violence or verbal abuse: debating is civilising.

The debate tool is used, after an activity of reading articles or resulting from group work, to memorise new information and link it to one's own knowledge. The debate then serves as a confrontation of the knowledge and representations of everyone, including those of the teacher.

For this course, students were asked to discuss the rise and fall of neonicotonoids. This activity was led by Björn K. Klatt from Lund University in Sweden.

After reading an online course on the impact of neonicotonoids on bees, the students had to think about argumentations from the different points of view of researchers:

(1) Farmers (plant protection, pollination, effort, financial survival)

Hughes, J., Reay, G., & Watson, J. E. (2014). Insecticide use on Scottish oilseed rape crops: historical use patterns and pest control options in the absence of neonicotinoid seed

treatments. *Proceedings Crop Protection in Northern Britain 2014.* (https://research-scotland.ac.uk/bitstream/handle/20.500.12594/151/CPNB_2014-Insecticide_use_on_oilseed_rape_crops.pdf?sequence=1)

(2) The chemical industry (financials, responsibility, policies)

Jeschke, P., & Nauen, R. (2008). Neonicotinoids—from zero to hero in insecticide chemistry. *Pest Management Science: formerly Pesticide Science, 64*(11), 1084-1098. (https://onlinelibrary.wiley.com/doi/full/10.1002/ps.1631?casa_token=f7aYBWLoSEkAAAAA %3AiniBgK7oPrDy7hvVISmhbUK-y6BDJKcLjWNTIO-morqjBZV3XTZs38QcYrzYZ8nGTHpjcb8SiuWMsA)

(3) NGOs (pollination, nature protection, non-toxic environment)

Pesticides, N. (2017). The Environmental Risks of Neonicotinoid Pesticides.(http://www.moraybeedinosaurs.co.uk/neonicotinoid/Environmental_Risks_of_neo nicotinoid_pesticides_a_review_of_the_evidence_post_2013.pdf)

(4) Policies (responsibility, mediation, food security)

Dicks, L. (2013). Bees, lies and evidence-based policy. *Nature News, 494*(7437), 283.(https://www.nature.com/articles/494283a)

Then, Students were divided into groups and should prepare a short presentation arguing from the point of view, either farmers, chemical industry, NGOs or policies. Each group will argue from only one point of view.

Different roles are given by the teacher: (1) the Moderator of the debate is incharge of the general conduct: respect for speaking time, listening to others, kindness, etc., (2)Reporters of the contents and the works: quick summary of the arguments put forward and give feedback and notes.

The key to the success of the Debate is to find a few students who 'initiate' the discussion to allow the exchange to take place. It is better if this comes from them than from the teacher.

The roles of moderators and reporters are also important.

It is also important that the documents provided are read before the discussion.

6. Conclusion

Pedagogical innovation and active pedagogy are very good ways to promote learning in Plant Sciences but also for all disciplines. On the other hand, they should not be considered as an end in themselves.

Students have different learning profiles, have different reactions and motivation depending on the topics taught but also in the way they are taught. The key to building an effective course is to diversify the activities. This includes moments where learning is transmissive as in the case of lectures, where learning is partly autonomous as in the case of flipped classes (the learning time of each student varies according to the class), where learning is peer learning as in the case of PBL (students are supported by tutors who are experts in the subject), where learning is collaborative/cooperative as in the case of serious games/debates/projects.

You have to be willing to experiment, to make mistakes, to adapt, to be right, to try again because it is the sum of all these pedagogical methods that create an innovative training and a wealth of sharing.
This is what we implemented during the Escapade project.