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### ► To cite this version:

Basile Ploteau, Guilhem Brunel, Léo Pichon, Arnaud Ducanchez, Thomas Crestey, et al.. Experiences with teaching precision agriculture through reverse pedagogy. 14th European Conference on Precision Agriculture, Jul 2023, Bologna, Italy. pp.1091-1098, 10.3920/978-90-8686-947-3\_137 . hal-04364106

**HAL Id: hal-04364106**

**<https://hal.science/hal-04364106>**

Submitted on 26 Dec 2023

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## **Experiences with teaching precision agriculture through reverse pedagogy**

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### **Abstract**

Precision agriculture (PA) technologies have been widely developed in agriculture over recent decades. Therefore, understanding the challenges of PA is a major issue in the training of agricultural students. Reversal pedagogy (RP) is an efficient pedagogical approach used to make a group of students understand key concepts when teaching courses that deal with complex and multi-disciplinary issues. An RP approach was implemented in a two-week introductory teaching unit on PA for a Master's degree course in France. The method allowed the students to be able, in a short period of time to, i) understand the main concepts of PA, ii) produce structured and scientifically relevant teaching resources and iii) train other students. The results demonstrated that RP is an interesting approach for teaching PA at universities.

**Keywords:** active-learning, competences, education, flipped classrooms, skills

### **Introduction**

Precision Agriculture (PA) uses advanced and emerging technologies, such as physical sensors, remote sensing, and geolocation, to improve the efficiency and productivity of agricultural practices. Therefore, understanding the issues of PA and the physical principles of key PA technologies is a major issue in the education of agricultural students. However, recent studies in several countries have shown that the majority of graduating agricultural students do not feel adequately trained in PA (Bournaris et al., 2022). The teaching of PA is complex because it involves many disciplines (physics, computer science, economics, sociology, etc.) framed in a multidisciplinary approach. Consequently, many traditional pedagogical approaches are not necessarily well-suited to teaching PA with its complex systems and technologies. McCubbins et al. (2018) described how a Team Based Learning (TBL) approach was used to teach farm management to a group of undergraduate students. In the TBL approach, the traditional model of the classroom is reversed, students construct their own knowledge from resources provided to them and teachers can use class time to follow students through hands-on activities and projects that help the students to apply their knowledge and skills. It has been proven that students' involvement is higher and their results are better with a TBL approach (Sisk, 2011). McCubbins et al. (2018) also demonstrated that this approach helps students to develop a deeper understanding of the complex concepts and could be used to teach a range of topics in agricultural education. The TBL approach has proven to be effective in a variety of fields, including engineering (Najdanovic-Visak, 2017), and can be particularly well suited to teaching PA. Reversal Pedagogy (RP) (Caillez and Hénin, 2017) is a special case of TBL in which students construct knowledge themselves and then teach it to other students. The purpose of this approach is to get a group of

students understanding key challenges and concepts in a relatively short period of time when teaching courses deal with complex issues and multiple topics. The RP approach includes i) a step of familiarisation with the subject by reading documents, ii) a step of organisation and prioritisation of the content and, iii) a step of production of teaching resources. This approach has never been reported for teaching tertiary-level PA courses. The RP approach was implemented in a two-week introductory teaching unit of a master degree course entitled 'information and communication technologies in agriculture (AgroTIC)'. The objective of this paper is to evaluate the relevance of the RP approach to educate students on key PA issues and technologies.

## **Material and methods**

### General RP approach

The general pedagogical approach of this study was derived from the Reverse Pedagogy (RP) approach as described by Cailliez and Hénin (2017). Students were brought to an active attitude inspired by flipped classrooms (Divjak et al., 2022) and active-learning strategies (Gleason et al., 2011). Their objective was to design a training session for other students. The approach consisted of three main steps: i) Students acquired a first level of knowledge on the basis of activities and documents (documents, videos, experts, etc.) provided by teachers, ii) they designed a teaching unit including theoretical and practical activities and finally iii) they led a training session for other students.

### Implementation of the RP approach

The RP approach has been implemented since 2016 and was evaluated in 2022 in a teaching unit for master degree students in France specialising in digital tools for agriculture. The unit is called AgroTIC and jointly taught between L'Institut Agro Montpellier and Bordeaux Science Agro. The teaching unit is an introduction to PA lasting 5 days over a two-week period. It was the first teaching unit of the semester in 2022 and 14 students attended. In parallel, student visits to companies that provide precision agriculture services were held.

The objective for the students was to develop general skills about the main topics of PA and to understand some key concepts (Table 1). Three technical topics (geolocation, optical and physical properties of the soil) in relation with farming practices and one transversal topic on services and uses of digital tools in a farming context were targeted. The three steps of the RP approach were implemented in five consecutive sessions (Fig. 1). The first step (acquiring a minimum level of knowledge) was carried out over two sessions (90-100 min sessions). Session 1 (Fig. 1a) was an introduction with a presentation of the deliverables and a self-assessment of the students' skills. Students also expressed their views and representations on PA during a moving debate (Fig. 1a). Session 2 was dedicated to the exploration of the three technical topics by three groups of students. The concepts of the transversal topic about services and uses were addressed during the exploration of the three technical topics. The objective was to identify the key concepts and main resources on these topics with the support of the teachers (Fig. 1b). The second step of the RP approach (designing the teaching unit) was carried out in two further sessions. The objective of the third session (0.5 day) was to stimulate the students' creativity (Fig. 1c). Firstly, the students worked in groups on an initial design of the teaching unit. After a first full draft, students were stopped and invited to look at and to improve the work in progress from the other groups. The aim of this cross-fertilisation

was to encourage the emergence of new ideas. Consequently, the resulting second drafts for each group contained ideas from the three different groups. At the end of the third session, the students all came together to define a common design for the training sessions. This led into a fourth session (run over three half-days) where each of the three groups designed in detail a training session related to one of the three topics (Fig. 1d). At the end of the fourth session, students were considered as “expert students” on the specific topic they had worked on. They were considered as non-expert on the other two topics.

Table 1. List of the topics and the associated key concept to be learned by students

Topics	Key concept
Geolocation	<ul style="list-style-type: none"> <li>- The principle of trilateration positioning</li> <li>- The main sources of error with geolocation</li> <li>- The difference between relative and absolute positioning error</li> <li>- Accuracy of correction systems and their different uses in agriculture</li> <li>- The functioning of the correction systems and their limits in agriculture</li> </ul>
Optical property measurements in precision agriculture	<ul style="list-style-type: none"> <li>- The working principle of an optical sensor</li> <li>- The different levels of information on a crop using ground-based measurements or remote sensing</li> <li>- The definition and the meaning of an indicator such as NDVI</li> <li>- The field impact of using a passive or an active optical sensor</li> <li>- The uses allowed by the spatial, temporal and spectral resolution</li> </ul>
Measurement of soil physical properties in precision agriculture	<ul style="list-style-type: none"> <li>- The stages of the data acquisition chain</li> <li>- The influence of the metrological characteristics of a sensor (precision, accuracy) on the agronomic interpretation</li> <li>- The difference between direct and indirect measurement of a variable</li> <li>- Differences between physical variables (electrical capacitance, conductivity, resistivity) on soil knowledge</li> <li>- Factors influencing the power autonomy of a sensor</li> </ul>
Services and uses of digital tools for crop, water and soil monitoring	<ul style="list-style-type: none"> <li>- Factors in the adoption of digital solutions on a farm</li> <li>- The obstacles to the adoption of digital solutions on a farm</li> <li>- A way to identify and classify the uses of digital tools on a farm</li> <li>- The range of prices of the main types of digital services</li> <li>- The services that support the deployment of a digital tool</li> </ul>

The third and final step in the RP approach was implemented in a fifth session. (Fig. 1e). It took place on a farm where fields and farming equipment were at the students' disposal. The groups of students were mixed up so that each new group contained expert students and non-expert students for each technical topic. During the training session, each student was alternatively in the position of a “teacher” for the topic he/she was expert on and a “student” for the topics he/she were non-expert on.

#### Evaluation of the approach

The relevance of the proposed approach was assessed by measuring the students' progression on the key concepts. This progression was estimated by self-assessment of the students before and after the training. For each self-assessment, they estimated a level of expertise for each of the four topics (Table 1) and each key concept. They chose their level of expertise as either: 1) unaware of the existence of the tool/key concept, 2) aware of the existence of the tool/key concept, 3) understands how the tool/key concept works, 4) is able to explain how the tool/key concept works or, 5) is able to give recommendations in a professional context taking into account the key concept.

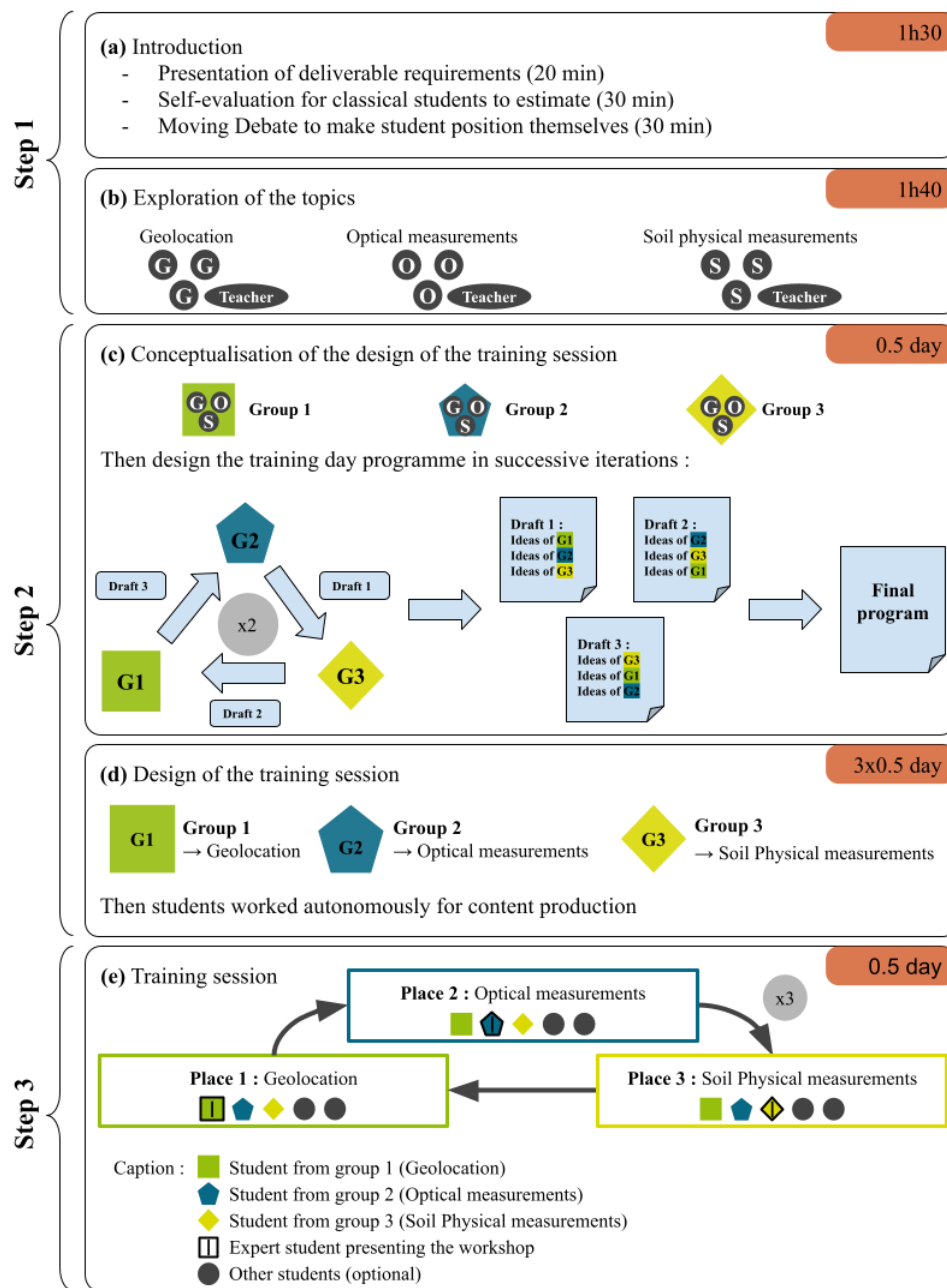


Figure 1. Implementation of Reverse Pedagogy for teaching Precision Agriculture to agronomy students: (a) Introduction and evaluation of the group’s initial perception of PA, (b) Exploration of the topics in thematic groups, (c) Conceptualisation of the design of the training session, (d) Design of a training session for each topic (geolocation, optical measurements and soil physical measurements) and (e) Delivery of the training session.

## Results and discussion

During the introduction, students attended workshops where they were able to express and discuss their views on PA (Fig 2a). Each student was briefed with basic knowledge of PA. Following this, the students created a complete ‘hands-on’ training workshop for one of the topics (geolocation, optical properties, soil physical properties) to understand the main concepts and to manipulate the associated tools and technologies (Fig. 2b). For

example, the students were able to handle optical proxy detection sensors or GNSS receivers with different correction systems. The key concepts were presented by the expert student of each topic using a large format printed poster.

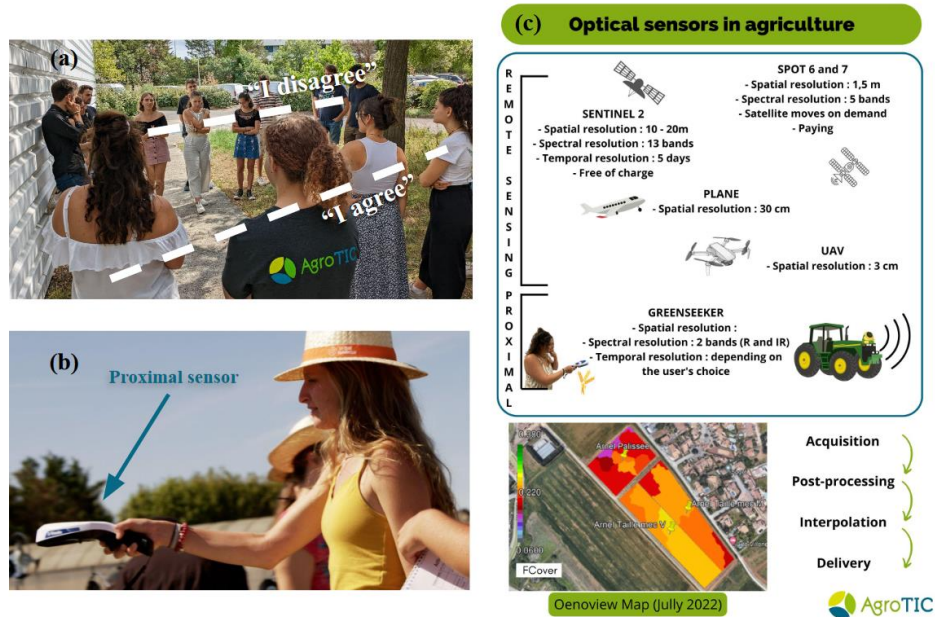


Figure 2. Illustrations of activities and productions carried out by students during precision agriculture teaching unit: a) students stand according to their agreement (front row) or disagreement (back row) with a statement made during the moving debate, b) students learned how to use a proximal sensor to understand optical properties and key associated concepts during presentation day and c) an example of a poster made by students for teaching to other students the key concepts of “optical properties” in PA.

As an illustration, Figure 2c presents the poster made for the “optical properties” topic. Similar posters were produced for the other two topics. During the workshop, the expert students made a presentation and led a practical training session. Then they moderated a discussion with the other students and answered their questions. A teacher was present in each workshop and did complete or correct the expert student's answers when it was necessary. The RP approach allowed students to learn concepts that were meaningful for them and appeared to encourage a better long-term understanding. Students were also developing professional skills needed by agronomists, such as an ability to find information on their own, to present figures and posters precisely, to concisely deliver key messages and to lead a training program. It is likely that by using classical teaching, it would have been more difficult to teach all the main concept in this short period of time. It is also likely that it would have been complicated to train students on transversal topic like time management and summarising the explanation of complex concepts.

The students' self-assessment of their global capability for each of the three topics allowed them to estimate and monitor their progress over the five days of training. For each of the three topics, students felt that they had made progress, which was reflected in a shift to a higher level of understanding. As an illustration of this, Figure 3 presents the self-assessment results for the geolocation topic showing the cohorts shift in improved understanding of the topic.

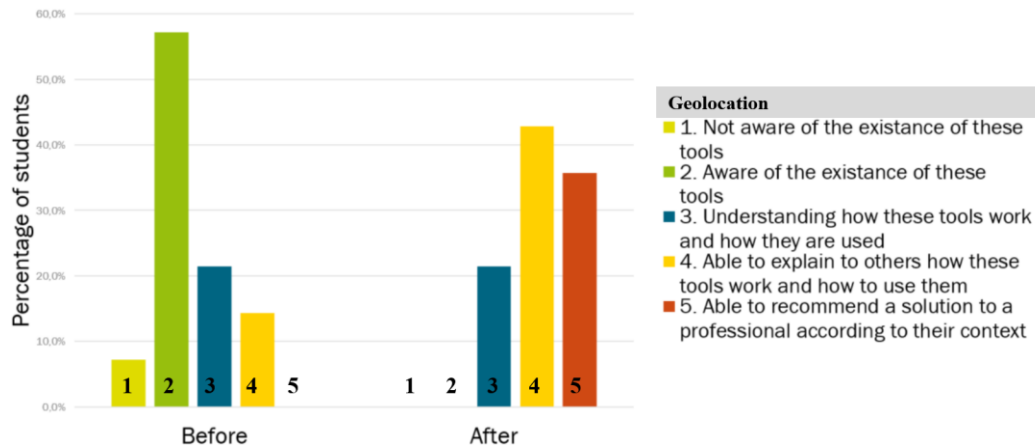


Figure 3. Students' self-assessment of their global capability concerning geolocation in Precision Agriculture before and after the teaching unit.

As can be seen in Figure 3, before the course, a majority of students were aware of the existence of geolocation tools but did not necessarily understand how they worked. After the course, most of them were able to explain how geolocation technologies work with 79% of the students self-assessing as being able to explain geolocation technology (category 4 or higher) and approximately a third of students were confident in their ability to recommend it (with an adapted correction service if necessary) in a professional context (category 5). It is worth noting that all the expert-students who designed the geolocation training workshop were in category 4 or 5. Similar results were obtained for the two other topics. After the training 71 % and 79 % of students self-assessed in category 4 or 5 respectively for “soil physical properties” and “optical properties” topics. Out of the 14 students, only two for the “soil physical properties” topic and one for the “optical properties” topic considered they had understood how the tools work but were not confident in explaining it to other students. For these three students, the five days of training might have been insufficient to master the key concepts studied. All the concepts introduced during this teaching unit were also developed during the following semester (in a more traditional setting) and allowed all students to ultimately master the topics. These results on student progression can be refined by studying the knowledge acquisition of the corresponding key concept for each topic. For most of the key concepts, the large majority of the students improved during the course and reached a minimum level of understanding (category 3 or higher) (Table 2). For a few key concepts, there was no progression made among the group of students. These concepts fell into two broad categories. Firstly, there were some technical key concepts that were just missed during the training sessions. For example, the “factors influencing the power autonomy of a sensor” were overlooked during the designing session (Fig. 1d), even if the teachers were being attentive, so no student expertise was developed and it was not taught within the delivered workshop. The second broad category involved key concepts related to the services and uses. These are complex and multidisciplinary concepts such as “A way to identify and classify the uses of digital tools on a farm”, which are difficult to fully develop in a restricted timeframe. Interestingly, some students had their own ideas and self-trust about it before the course, but appeared to arrive at a decision that it is more complicated than they thought by the end of the course. This, in itself, demonstrates a much deeper appreciation and understanding of the delivery of PA services.

Some technologies, such as mapping or wireless sensor networks, were omitted voluntarily during the teaching unit as they were developed in specific teaching units in the following semester. A noted advantage to the RP approach was an apparent higher level of student motivation as no absentees or late arrivals were observed (which is consistent with previous years as well). The students viewed this course as an opportunity to get to know each other and to know how to work efficiently in groups, which does help them in subsequent courses/semesters.

Table 2. Change in the percentage of students self-assessing at level 3, 4 or 5 of knowledge acquisition before and after the teaching unit for each key concept.

Topic	Key concepts	Before (a)	After (b)	Progression (c)
Geolocation	The principle of trilateration positioning	21%	79%	58% <span style="color: green;">++</span>
	The main sources of error	0%	93%	93% <span style="color: green;">+++</span>
	The difference between relative and absolute positioning error	0%	93%	93% <span style="color: green;">+++</span>
	Accuracy of correction systems and their different uses in agriculture	0%	0%	0% <span style="color: red;">=</span>
	The functioning of the correction systems and their limits	0%	36%	36% <span style="color: orange;">+</span>
Optical property measurements in precision agriculture	The different levels of information on a crop using ground-based measurements or remote sensing	21%	100%	79% <span style="color: green;">+++</span>
	The meaning of an indicator such as NDVI	29%	86%	57% <span style="color: green;">++</span>
	The working principle of an optical sensor	14%	79%	65% <span style="color: green;">+++</span>
	The difference between a passive and active sensor	0%	93%	93% <span style="color: green;">+++</span>
	The uses allowed by spatial, temporal and spectral resolution	29%	93%	64% <span style="color: green;">+++</span>
Measurement of soil physical properties in precision agriculture	The stages of the data acquisition chain	0%	86%	86% <span style="color: green;">+++</span>
	The influence of the metrological characteristics of a sensor on the agronomic interpretation	14%	79%	65% <span style="color: green;">+++</span>
	Difference between direct and indirect measurement	14%	93%	79% <span style="color: green;">+++</span>
	Differences between soil physical variables	0%	93%	93% <span style="color: green;">+++</span>
	Factors influencing the power autonomy of a sensor	7%	0%	-7% <span style="color: red;">=</span>
Services and uses of digital tools for crop, water and soil monitoring	Factors in the adoption of digital solutions on a farm	7%	93%	86% <span style="color: green;">+++</span>
	The obstacles to the adoption of digital solutions	21%	93%	71% <span style="color: green;">+++</span>
	A way to identify and classify the uses of digital tools on a farm	14%	0%	-14% <span style="color: red;">=</span>
	The range of prices of the main digital services	0%	36%	36% <span style="color: orange;">+</span>
	The services that support the deployment of a tool	7%	79%	72% <span style="color: green;">+++</span>



In this context, the reverse engineering pedagogy did have some specific requirements to be relevant for students. i) The teaching period had to be grouped in a two-week period as it was considered overly complicated to keep the motivation of students if the training was spread out over several months. ii) It required a multidisciplinary teaching staff. In the case presented above, nine teaching staff were involved, one professor who coordinated the course, three lecturers were involved in training the students on technical topics and a further five experts/teaching staff were required to provide technical advice to the students to enable them to deliver the workshops and field demonstrations. iii) Easy access to sensors and PA tools for students was necessary in order to let them design adapted practical exercises. These requirements do impose restrictions on the ability to apply the RP approach universally across the entire AgroTIC Masters course.

## Conclusions

This introductory PA teaching unit has three purposes: i) to use the RP approach to train students about PA within a professional context, ii) to introduce multi-disciplinary PA concepts and, iii) to enable students to better know each other in order to create a group dynamic for the coming year. For these three objectives, reverse engineering pedagogy proved to be an effective and interesting method. In particular, the RP approach allowed the students to obtain a better overview and understanding of PA technologies by promoting a progression in the mastering of several key concepts.

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