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Statistics inquiry and the students' engagement in the change of paradigm

Maria-Josep Freixanet¹, Montserrat Alsina¹ and Marianna Bosch²

¹Universitat Politècnica de Catalunya, Spain; maria.josep.freixanet@upc.edu

²Universitat de Barcelona, Spain

The Anthropological Theory of the Didactic introduces an instructional proposal called “study and research paths” (SRPs) based on the study of open questions that integrates inquiry processes with the study of new content to elaborate answers to the questions addressed. The aim of this paper is to analyse the students' perspectives to an activity carried out as an SRP to teach statistics in grade 10 and compare it to a previous one implemented as a more traditional statistical project. The analysis is based on the results of a survey and semi-structured interviews to students who participated in both the SRP and the project activity. They show an increase of students' responsibilities in the inquiry process and an improvement of their engagement.

Keywords: Paradigm of questioning the world, anthropological theory of the didactic, statistics, secondary school mathematics, student reaction.

Introduction: projects, statistics, and the paradigm of questioning the world

The importance of projects has always been stronger in the teaching of statistics than in other subject matter topics and many researchers highlight the benefits of its use. Batanero et al. (2011 p. 21) mention that “statistics projects raise the motivation of students”. Frischemeier et al. (2022) claim that teachers' goal as educators is to engage students in statistical thinking and reasoning, and advice teaching statistics through projects and investigations. They also highlight the need to address meaningful problems that may have personal relevance to learners or engage them in considering real life global problems and challenges. The use of real or realistic data is also pointed out as an issue that can motivate learners to use statistical and probabilistic ideas in their thinking and reasoning. Gómez-Blancarte and Santana (2018) ensure that working with projects can enrich curricula; and statistics literacy, reasoning and thinking can be adequately addressed since they can be used as the foundation of projects. Also, Garfield et al. (2008) reinforce the idea of fostering active learning with projects, lab exercises, group problem solving and discussion activities. Ben-Zvi et al. (2019) proposes a statistical learning environment with six components, one of them being establishing a culture classroom that fosters statistical arguments. They point out that “the shift in the classroom culture is related to a potential shift in the role of the students, from problem solvers to statisticians who analyse and represent data to make them easily accessible for decision makers”. In the analysis of some statistics and probability texts in Chilean upper secondary curriculum carried out by (Elicer, 2019), the role of decision-making as legitimation of the subject matter is evident and the author claims there is a shift increasing students' responsibility in the educational process.

This paper adopts as research framework the Anthropological Theory of the Didactic (ATD, Chevallard, 2015). Student-centred approaches such as inquiry-based and project-based learning are conceptualised in the ATD from a broader perspective by considering two main pedagogical or school

paradigms: the *paradigm of visiting works* where a knowledge-based study method prevails, and the *paradigm of questioning the world*, a question-centred form of study where questions go first, and knowledge works are used and studied to elaborate answers to the questions. Instructional processes within the paradigm of questioning the world are described as *study and research paths* (SRPs). An SRP begins with a generating question that is given to the students, who address it under the guidance of the teacher(s). In the process of answering the generating question, new derived questions arise that the study community (made of teachers and students) need to answer to develop the inquiry. Addressing the derived questions requires searching already available information (knowledge works, empirical data, etc.) and studying it. However, even if new knowledge needs to be searched, newly elaborated and acquired to produce the final answer to the generating question, in the paradigm of questioning the world the main aim of the study is to answer the question addressed, not to build new knowledge. Markulin et al. (2022) present a comparative analysis of the ATD proposal in terms of SRPs and other forms of project-based learning, especially connected with statistical education.

Two consecutive project-based instructional proposals

This paper shows the students' perceptions of two different project-based activities carried out during two consecutive school years in the subject of statistics in grades 9 and 10 of secondary school, especially focusing on the degree of students' involvement and engagement in the activities. The first activity (A1), called "The noise and how it affects our health", was designed under no theoretical framework. It was developed in 2020-21 with grade 9 students as a project-based activity to develop statistics curricular content covering descriptive statistics, including data gathering, organisation, measures, graphics, etc. After the activity finished, an analysis using the ATD was carried out (Freixanet et al., 2022a). The main conclusions in our analysis were: (1) although the students, working in teams, addressed the same questions, there were few opportunities for collaboration and sharing; (2) the teacher assumed too much responsibility in both the design and implementation of the instructional proposal, in particular, most of the information and the tools needed for the project were brought by the teacher; and (3) the students did not have the whole perspective of the project and only carried out the activities they were successively told.

The second activity (SRP1) was carried out the following year by two groups of 30 grade 10 students and one teacher. The design and the first phases of the implementation are explained in (Freixanet et al., 2022b). The generating question was "Are we eco-friendly?". SRP1 had two main goals to accomplish after the analysis of A1, apart from learning the statistics concepts required in the curricula. These were: (1) giving the students more autonomy, responsibility, and power of decision, and (2) making the work all together, sharing the results with all the classmates and the two groups. To accomplish (1), more time was devoted to sharing the information, making proposals about how to continue the work, and agree on how to do so. To fulfil (2), all the agreements and documents generated were shared through Google Drive and the Moodle course.

SRP1 was divided in different phases (Table 1). In phase 1, secondary data were searched and shared, the research goals and the experiment design were set. In phase 2 (implementation), two surveys were prepared, one to gather information about the students' previous recycling knowledge and the other to collect data on the waste weight from the bins in the school yard. The first survey was analysed in

this phase: data were cleaned, organised and graphics were made. In phase 3, the descriptive analysis of the weighed data was carried out using frequency tables, means, standard deviations, coefficients of variation and graphics. Scatter plots and Pearson’s correlation coefficient were used to prove if the campaign had had any impact. Each team elaborated a report and a video.




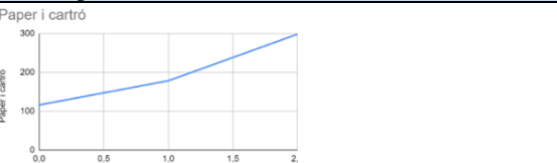
Phase 1: Information search and sharing (padlet, G. Docs). Research goals. Experiment design.																					
	<ul style="list-style-type: none"> • How aware are the secondary students about recycling and separating waste? • How much waste they produce after the morning break? • Do they separate waste properly? • Carry out a campaign to raise awareness and check if it has any impact. 	<ol style="list-style-type: none"> 1. Survey about previous knowledge. 2. First data collection. 3. Campaign implementation. 4. Second data collection. Analysis. 5. Campaign: relay game. 6. Third data collection. Analysis. 7. Survey about previous knowledge. 8. Has the campaign had any effect? 																			
Phase 2: Survey about the students’ previous knowledge, results. Data collection (waste weight).																					
																					
Phase 3: Analysis of the collected data. Report and video.																					
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Table 1: General overview of SRP1

Due to the high amount of work, the teacher introduced a new figure, called “middle-level management” (MLM), within the students’ community in phase 2. Their responsibilities were: supervising their classmates’ work, communicating with the other MLM-students and the teacher. Students decided whether they wanted to adopt this role. Twenty students volunteered. In the end, four teams (19 students) submitted their study to a national statistics projects contest, 17 of which were MLM-students. In this context, we formulate as research questions:

RQ1: What were the students’ perceptions of the SRP in terms of decision-making, participation, collaboration, teamwork, responsibilities, and their own engagement?

RQ2: What, if any, differences did students notice between A1 and SRP1?

To address these questions, at the end of SRP1, the students were asked to answer a survey, 50 responses were gathered. Semi-structured interviews were also carried out with 16 students of different performance levels. We present here the information obtained and our interpretation to compare SRP1 with A1 and analyse the new conditions introduced to foster the inquiry process.

Students’ perceptions of the SRP

Survey

The survey was divided in five sections: general aspects, digital competences, mathematical competences, social and personal competences, and the future of the “projects”. The first four sections

had a question with various items to be evaluated through a Likert scale from 0 to 3, with the options “Not at all”, “Little”, “Quite”, “A lot”, and the option “I don’t know”. In addition, there was an open-answer question. In the last section, the students were asked about the future of this way of learning, if it should be kept, why, if their learnings were useful and what they would improve in future projects. In this paper, we are going to focus on the survey’s first section.

This first section comprises the question: “Evaluate the following aspects from the statistics project”. The aspects chosen are directly related to our study focus explained in the introduction: “Decision-making and participation”, “Organisation”, “My engagement” and “I’ve enjoyed the project” are related to goal (1); “Teamwork” and “Collaborative Work”, to goal (2). Other aspects were added considering the analysis carried out in A1. Since the students did not have the whole perspective of A1, and SRP1 was designed differently, it was also important to know their perception about the “Planning” and if they had achieved the whole perspective of “How to carry a research work”. A descriptive analysis and the graphics are shown in the table and figure below:

Items (from highest to lowest answers)	Mean	SD	Median	Interquartile range (Q3 – Q1)
Decision-making and participation (DP)	2,39	0,79	3	1
Teamwork (TW)	2,33	0,77	2	1
My engagement (I)	2,22	0,76	2	1
Collaborative work (CW)	2,02	0,79	2	1,5
How to carry out a research work (R)	2,00	0,86	2	2
Organisation (O)	1,75	0,89	2	1
I’ve enjoyed the project (E)	1,62	0,92	2	1
Planning (1 weekly session) (P)	1,60	0,79	2	1

Table 2: Descriptive analysis of the first section of the survey and some students’ comments

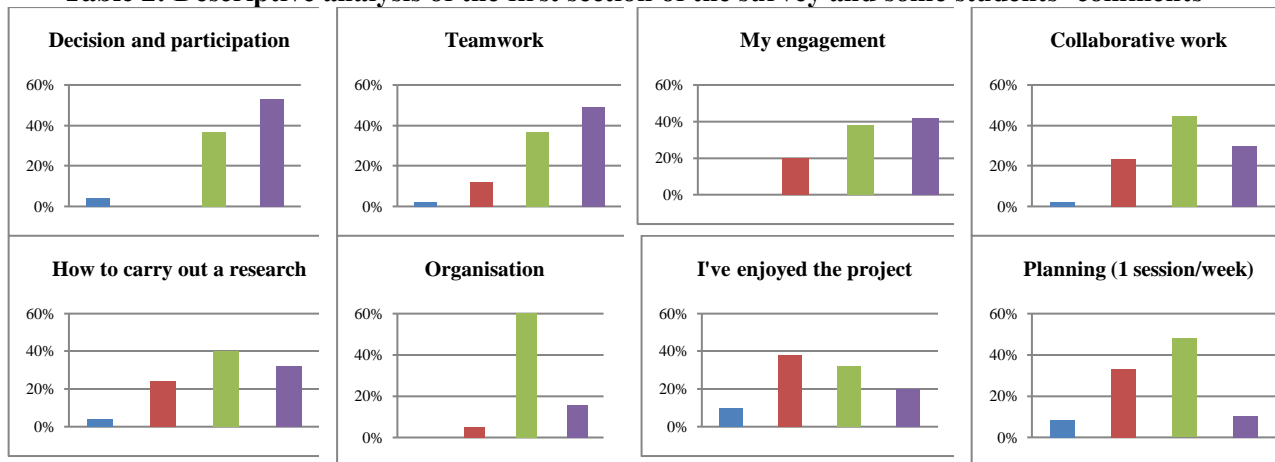


Figure 1: Answers to the first section (blue: not at all, red: little, green: quite, purple: a lot)

Table 2 shows that all the items’ means are above the average, but O, E and P get the lowest scores. What the students value the most is DP and TW. The median and the graphics show that all distributions are left-skewed, except for E, which presents a more symmetrical distribution.

The students left 27 comments, which have been classified among the items analysed (Table 3).

Decision-making participation (DP)	<i>I find it very interesting that we organised a big part of the work and that we did most of the things, but I missed some more guidelines. // I liked the chance to choose what part of the SRP each team wanted to investigate. We had more freedom than in the previous project.</i>
Teamwork (TW)	<i>We have organised properly within our teams. // It is necessary to work in teams in such projects due to the workload. // The teams should have been set by the students, not the teacher.</i>

My engagement (I)	I think I could have been more engaged in some parts of the work
Collaborative work (CW)	<i>The work between the two groups was useful and original. // Both groups showed engagement and collaborated in a correct and efficient way. // The data sharing with the other group facilitated the SRP organisation. // We hardly spoke about the work done with the other group.</i>
How to carry out research work (R)	<i>It was very useful to learn how to carry out an investigation, a report and all their parts. // Since I was in the “campaign” team, I did not learn much of the research process.</i>
Organisation (O)	<i>Everyone organised well within their teams. // The fact of sharing the information with the other group facilitated the organisation to carry out the project. // We should have organised better because we did not have the time to finish everything. // I missed more guidelines.</i>
I've enjoyed the project (E)	<i>I enjoyed the project. // I loved the project. // I did not enjoy the project because of the topic, the data gathering (weighing the waste) was not very enjoyable.</i>
Planning (P)	14 out of 15 comments asking for more time in class to work in these types of projects.

Table 3: Some students' comments about the SRP (comments in italics are positive; in red, negative)

Interviews

Researchers Y. Chevillard, M. Bosch and M. Alsina conducted three semi-structured interviews to 16 students divided in three groups. Group 1 was formed by five students that had been awarded with the previous year project A1. They are highly motivated, critical students. Group 2 was formed by five students with poor learning skills in general and two of them did not hand out the final report and video of the SRP. The third group was a mixture of students: three girls with medium mathematical skills and three boys with high mathematical skills. Surprisingly, the three girls were part of the MLM-team and submitted their final work to the contest in two different teams, whereas the boys, with higher mathematical skills, did not; only one of the boys was part of the MLM-team.

Table 4 presents the students' comments related to the aspects considered in this communication:

Decision-making participation (DP)	G1 agreed that they liked the fact of having the freedom to decide how to focus their work and “organise and carry out our own statistical study”.
Teamwork (TW)	There were different opinions in this matter: G1 were critical with the teamwork, they believed they had to motivate their teammates to get the work done; G2 and G3 thought it worked well, except two students who said their team had learning difficulties, that hindered the work.
My engagement (I)	G1 believed the engagement was closely related to the motivation of the students and it had a direct impact on the teamwork. They thought there were different levels of engagement
Collaborative work	Nothing was commented on this aspect.
How to carry out research work (R)	When they were asked what they had learnt with the project, G1 mentioned the different parts of doing research work: previous study, how to make a survey, data analysis, writing a report... whereas the other groups mentioned only certain activities: how to make surveys, graphics...
Organisation (O)	In the end, some students changed teams to submit the project to the contest. Some students believe these teams should have been done for the beginning of the SRP.
I've enjoyed the project (E)	There were different opinions on this matter, the commonality was that all of them had enjoyed the parts they had been responsible for: video, relay game, data gathering, report...
Planning (1 weekly session) (P)	G1 and G3 agreed that there was too little time in class to do the amount of work required and they had to work a lot at home, although one student pointed out it was a matter of team organisation. G2 believed they had enough time to finish their work in class.

Table 4: Responses of the students during the interview

Considering the descriptive analysis of the survey and the comments, both from the survey and the interviews, what the students valued the most was the chance and freedom to make decisions along the SRP. Teamwork was also high valued, although some students believed they should have chosen the teams. Different levels of engagement can be noted, with a high mean. CW and R got similar evaluations with mostly positive comments. E presented the highest standard deviation value and

comments saying they had enjoyed the parts they were responsible for. Many comments were given about the shortage of time to finish all the tasks required (P).

Differences between MLM- and non-MLM-students' perceptions of the SRP

Since a new students' role appeared in SRP1, we believed it was necessary to see if there was any difference of perceptions between the MLM- and the non-MLM-students. To compare them, the same descriptive analysis as in the previous section was performed but separating both types of students and a Wilcoxon non-parametric test was carried out considering (Table 5).

	Mean			Median		SD		IQR	
	MLM	\overline{MLM}	p-value	MLM	\overline{MLM}	MLM	\overline{MLM}	MLM	\overline{MLM}
Dec-making & participation (DP)	2,83	2,13	0,000	3	2	0,3835	0,8462	0	1
Teamwork (TW)	2,72	2,06	0,003	3	2	0,4609	0,8139	1	1
My engagement (I)	2,83	1,88	0,000	3	2	0,3835	0,7071	0	1
Collaborative work (CW)	2,11	1,97	0,299	2	2	0,7584	0,8230	1	2
How to do research (R)	2,44	1,75	0,003	3	2	0,7048	0,8424	1	1
Organisation (O)	2,11	1,53	0,020	2	2	0,4714	1,008	0	1
I've enjoyed the project (E)	2,17	1,31	0,000	2	1	0,7071	0,8958	1	1
Planning (1 sess/week) (P)	1,61	1,60	0,482	2	2	0,6978	0,8550	1	1

Table 5: Descriptive analysis and p-values comparing MLM- and non-MLM-students

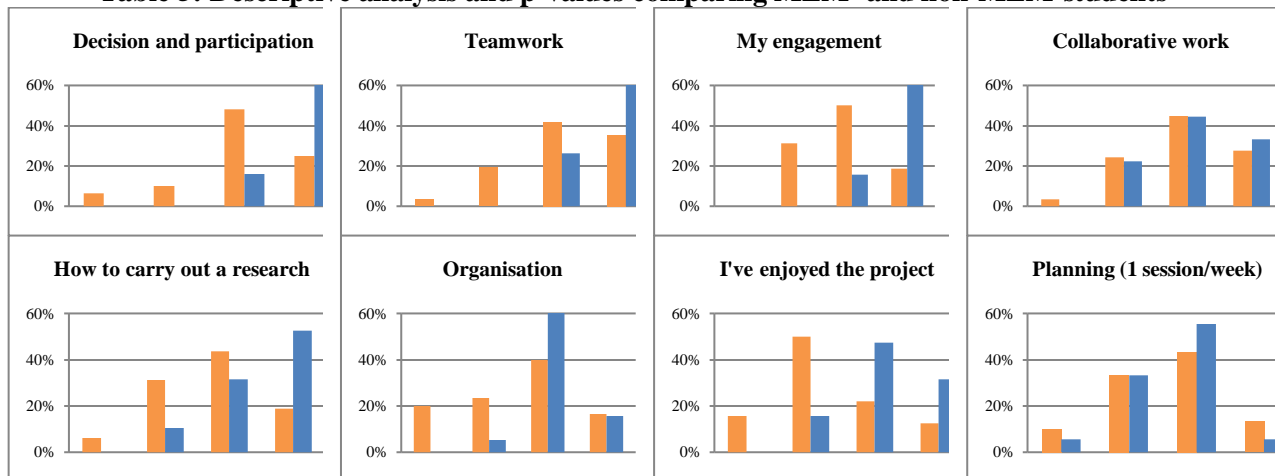


Figure 2: Graphics distinguishing MLM- (blue) from non-MLM-(orange) students

We find six aspects: DP, TW, I, R, O, E, where the answers of MLM and non-MLM students are significantly different, and MLM-students have higher perceptions. In CW and P, not such a difference can be noticed. It can also be seen that the responses of the MLM-students are also more homogeneous in DP, TW, I, O. However, in CW, R, E and P, both groups have a similar deviation.

Comparison between the SRP and the project-based activity

The students were asked through a survey and within the interviews if they had noticed any differences between A1 and SRP1. The survey also asked why and to write down positive and negative aspects of each one. 19 students answered it, from which 68,4% noticed differences. Concerning the focus of our study, Table 6 shows some comments about the differences noticed:

“More freedom this year while working. There was no need for all the teams to do the same”. //

“All the classmates have been more involved, and the distribution and collaboration have been better”. // “The organisation, the involvement of the class and more statistical tools”. // “The project had no prior guideline. We have implemented it as we went along”.

When asked about positive and negative aspects of A1 and SRP1, the answers were:

	A1	SRP1
Decision-making participation (DP)	<i>The students didn't have any idea about the final results // No freedom of choice.</i>	<i>More autonomous.</i>
Teamwork (TW)	<i>It was a project to be worked in teams</i>	<i>Good distribution of the work.</i>
My engagement (I)	<i>Not everyone gathered data. The students were not very involved.</i>	<i>Everyone knows what the work is about.</i>
Collaborative work (CW)	<i>The students did not cooperate much/ The students didn't have an idea about the final results</i>	<i>High contribution among all the students // Poor coordination between teams.</i>
Organisation (O)		<i>Sometimes I was lost.</i>
I've enjoyed the project (E)	<i>It was satisfying to finish it and see the work done. // The process was lousy and boring due to the data gathering and surveys after class, un motivating</i>	<i>It has been fun.</i>
Planning (P)		<i>Too few classes during the week.</i>

Table 6: Students' comments about positive (black) and negative (red) aspects about A1 and SRP1

In the interviews, G1 saw a big difference between A1 and SRP1 in terms of freedom in taking decisions and organising their own work. They believed, though, it was a strategy adopted by the teacher since the previous year, A1 had been a totally guided activity. G2 and G3 did not have the feeling of having carried out a complete study, only the ones who submitted the project to the contest had. They pointed out they had done some activities, taken some measures, gathered data through a survey, but they saw these as unconnected activities. These comments reinforce one of the conclusions of the analysis of A1 mentioned in the introduction about the students missing the whole perspective of the project and only carrying out the activities proposed by the teacher.

Conclusion

We can conclude that our analysis of the comparison between A1 and SRP1 finds an echo in students' voices. The students' perceptions in terms of decision-making, participation, teamwork, collaboration, and their engagement got high scores, even higher when taking more responsibilities along the SRP. Regarding the differences, the students may have noticed, we can state:

- (1) Students did notice differences between the activity implemented as an SRP and the project. The differences mainly correspond to the changes wished, especially in the freedom given to students to make their own decisions, and in the collaboration and responsibilities assumed.
- (2) Students attribute the increase of responsibilities they had to assume to a teacher's strategy. They thought the first activity was more guided because they were new to it. The second one could be less guided since they already knew some aspects of the inquiry process: searching for information, designing a survey, collecting data, analysing the collected data, etc.

It appeared to us that what students perceived as a teaching strategy—a first guided inquiry followed by a more open one—could be introduced in future implementations on purpose, thus proposing a progressive share of responsibilities between teacher and students during the different implementations of the SRP in consecutive courses. These are of course very concrete conditions. The idea of “transition implementations” of the SRPs and a gradual evolution of the didactic contract

emerges after this study. This idea could be related to some kind of “statistical general methodology” that appears in almost all statistical projects (relating questions to statistical variables, survey design, data gathering, analysis, report writing, etc.). What aspects should be left to the students gradually and how is an open question to be explored.

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