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► To cite this version:

Marianna Bosch, Berta Barquero, Ignasi Florensa, Noemí Ruiz-Munzon. How to integrate study and research paths into university courses? Teaching formats and ecologies. INDRUM 2020, Université de Carthage, Université de Montpellier, Sep 2020, Cyberspace (virtually from Bizerte), Tunisia. hal-03113981

HAL Id: hal-03113981

<https://hal.science/hal-03113981>

Submitted on 18 Jan 2021

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How to integrate study and research paths into university courses? Teaching formats and ecologies

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The implementation of inquiry-oriented instructional proposals at university level collides with many constraints related to the current pedagogical paradigm based on the transmission of previously established knowledge organisations. One of them is the fact that subject's agendas are determined by a set of topics to study, not of questions to inquire about. Our research team has worked during this last decade in the design and implementation of an inquiry-oriented instructional format called study and research paths (SRPs) within the Anthropological Theory of the Didactic. This paper focuses on different ways of integrating SRPs in current university teaching, by linking inquiry to the study of knowledge organisations, without considering it only as a means to better learn the curricular content.

Keywords: Teachers' and students' practices at university level, Novel approaches to teaching, curricular and institutional issues concerning the teaching of mathematics at university level, anthropological theory of the didactic, inquiry-oriented instruction.

INTRODUCTION

Current university instruction is mainly embedded in what has been called the *paradigm of visiting works* (Chevallard 2015), where teaching and learning goals always include a list of works of knowledge students have to study. Teachers know in advance the knowledge works or topics that determine the course content. Their responsibility consists in organising productive visits to these works for the students. The students, in turn, are required to encounter the works that shape the syllabus of the course and be able to activate them in certain situations, for instance, to solve problems, make analyses and elaborate on them. The paradigm of visiting works is nowadays evolving towards a new pedagogical paradigm that is characterised in the ATD as the *paradigm of questioning the world*. Instead of works to visit, this paradigm is based on the approach of open questions students carry out under the guidance of the teachers, thus developing inquiry processes characterised as *study and research paths* (SRP).

As happens with other forms of inquiry-oriented instructional proposals, the implementation of SRPs at university level collides with many constraints linked to the current pedagogical paradigm of visiting works. One of them is the fact that university subjects are determined by a set of works of knowledge to study, not of questions to inquire about. In this situation, inquiry activities need to be related to previously established topics. Otherwise, they run the risk of appearing as “extracurricular” and end up disappearing. Relevant investigations about inquiry-oriented teaching in

undergraduate mathematics focus on given bodies of knowledge (differential calculus, linear and abstract algebra, differential equations, etc.) and show how inquiry processes help students create a better approach to them (Larsen, 2013; Rasmussen, Kwon, Allen, Marrongelle, & Burtch, 2006; Wawro, 2015; Zandieh, Wawro & Rasmussen, 2017). As stated by Kuster, Johnson, Keend and Andrews-Larson (2017, p. 3):

[Inquiry-oriented] activities promote the emergence of important student-generated ideas and solution methods, which one can think of as the mathematical “fodder” available to the teacher for the progression of the mathematical agenda.

This *curriculum constraint* can have as a consequence the consideration of inquiry activities as a means to better acquire a given content, without letting them being the core of the content to be taught and learnt. This reduction can explain why many investigations about inquiry-based teaching at the university seem to oppose it to more transmissive (or traditional) instructional formats as if one approach could only exist to the detriment of the other (see, for example, Khalaf, 2018).

The approach in terms of SRPs do not oppose inquiry with transmission, but on the contrary relate them dialectically through the notions of “study” (consulting existing knowledge, attending lectures where the teacher acts as the main media to provide mathematical knowledge, etc.) and “research” (inquiry, problem solving, problem posing, etc.) (Winsløw, Matheron, & Mercier, 2013). As has been illustrated in (Barquero, Monreal, Ruiz-Munzón, & Serrano, 2018), SRPs need the interaction and combination of inquiry-based learning devices with others more based on the transmission of knowledge. This dialectic can also be seen as a reverse in priority: instead of using inquiry activities to help students learn a given work of knowledge, in an SRP, students have to learn works of knowledge to carry out their inquiry better.

Our research team has worked during this last decade in the design and implementation of SRPs at university level (Barquero, Bosch, & Gascón 2011, 2013; Barquero et al., 2018; Bartolomé, Florensa, Bosch, Gascón, 2018; Bosch, 2019; Florensa, Bosch, Gascón & Mata, 2016; Florensa, Bosch, Gascón, & Winsløw, 2018; Serrano, 2013; Serrano, Bosch & Gascón, 2010). We used different strategies to deal with the curriculum constraint and integrate SRPs into the current instructional organisations as official teaching and learning activities. This paper aims to examine these strategies and highlight some of their drawbacks and advantages. The research questions underlying the analyses can be formulated as:

RQ1. How can SRPs be integrated into current university instructional formats that are subject to specific constraints of the paradigm of questioning the world? What elements of the SRPs’ organisation foster their sustainable implementation? What elements hinder it?

RQ2. How does the implementation of SRPs affect the content organisation of the subject? What aspects of the knowledge works that define the agenda of the course evolve and how? Which other remain as constraints difficult to overcome?

These questions are addressed by considering seven implementations of SRPs as case studies. The research here presented is still in an exploratory stage, where the main indicators of the different cases are identified to formulate hypotheses about the problem of the ecology and sustainability of SRPs and, more generally, about the possible ways to foster the transition between the paradigm of visiting works and the paradigm of questioning the world. The next sections present the main elements of SRPs and the courses where they were implemented, considering three main modalities. A summary of these elements will be presented in the conclusion sections as preliminary propositions to be tested with further research.

THE IMPLEMENTATION OF SRP: DIFFERENT MODALITIES

SRPs are initiated by a *generating question* (Q_0) addressed by a community of study (a set of students X and a set of guides of the study Y) that form a *didactic system* $S(X, Y, Q_0)$. The aim of the didactic system is to generate a final answer A^\heartsuit to question Q_0 . The work of the community of study and the knowledge involved can be described as a concatenation of derived questions and the development of their associated answers that will lead to the elaboration of A^\heartsuit . The inquiry process will combine moments of *study* of information available in different sources – the *media* – with moments of *research* and creation of new questions and answers, including the adaptation of the information to the specific (initial and derived) questions addressed. Any kind of tools and knowledge productions used in the study and research process is progressively integrated into the *milieu*, which provides the resources needed to answer the initial question Q_0 . This process can be summarised in the following schema, where the A_i^\diamond are bodies of knowledge accessible to the study community that help to answer the derived questions Q_k using the already available works W_j :

$$[S(X; Y; Q_0) \Rightarrow \{ A_1^\diamond, A_2^\diamond, \dots, A_i^\diamond, W_{j+1}, W_{j+2}, \dots, W_j, Q_{k+1}, Q_{k+2}, \dots, Q_n \}] \Rightarrow A^\heartsuit$$

In the paradigm of visiting works, a predominance is given to the set of bodies of knowledge A_i^\diamond students are required to study, while the questions Q_k usually arrive at the end of the instructional process, as possible applications. In an inquiry process, what is important is the question Q_0 that is to be answered, while in the paradigm of visiting works learning processes focus on some pre-existing answers A_i^\diamond . Of course, behind any work to visit there exist questions that were once important to elaborate the answers, but what is put forward are the works – the answers – not the questions.

The contra posed role between questions and answers appears as an important constraint for a sustainable implementation of inquiry-oriented teaching processes. SRPs are not an exception.

Table 1 presents a brief account of some SRPs that were implemented in university courses of mathematics and engineering subjects. We will focus on the different modalities adopted to integrate them into the traditional organisation of the courses.

SRP	Subject / SRP questions	Level and degree	Period	References
SRP1	<i>Mathematics</i> Population dynamics	1 st -year Chemical engineering	2005-2009	Barquero et al (2011; 2013)
SRP2	<i>Mathematics</i> Sales predictions; Organising a bike-sharing system	1 st -year Business administration	2006-2014	Serrano (2013), Serrano et al (2010)
SRP3	<i>Mathematics</i> Evolution of Facebook users	1 st -year Business administration	2015-2017	Barquero et al (2017)
SRP4	<i>Strength of materials</i> How to make a slatted bed base?	3 rd -year Mechanical engineering	2015-2018	Bartolomé, Florensa, Bosch, Gascón (2018)
SRP5	<i>General elasticity</i> How to make a bike part?	2 nd -year Mechanical engineering	2015-2018	Florensa et al (2016) Florensa et al (2018)
SRP6	<i>Statistics</i> Data analysis for an investigation on consumer behaviour	2 nd -year Business administration	2018-2020	(in process)
SRP7	<i>Mathematics</i> Progressive discounts	1 st -year Business administration	2018-2019	(in process)

Table 1. List of experienced SRPs

SRP1 and SRP2 were organised as workshops that run in parallel to the regular annual course, as weekly 2-hour sessions for a total of 60 hours both, thus complementing the lectures and problem sessions. SRP3 was organised in a similar way but for a quarterly subject and run for a shorter time (9 sessions of 2 hours). In the three cases, the activities were inserted in an instructional device called “Modelling workshop”, to differentiate them from the lectures and problem sessions or tutorials. The subject of SRP4 was fully organized as an SRP lasting a whole 6 ECTS subject (17 weeks, 4 hours per week). The last ones, SRP5-SRP7 were implemented at the end of the courses, after 8-10 weeks of traditional lectures, labs and problem sessions. SRP5 run for the seven last weeks of the course, thus covering a total of 28 h, while SRP6 and SRP7 only run during the three last weeks (12 h in total). In these three cases, the work done in the SRP was named as the “Final project” of the subject.

We can, therefore, distinguish three modalities of integration: SRPs running in parallel to the traditional organisation of the subject (SRP1-SRP3, Modelling workshop); SRPs organised at the end of the subject (SRP5-SRP7, Final project) and a subject totally organised as an SRP (SRP4).

SRP IN PARALLEL TO THE COURSE: “MODELLING WORKSHOPS”

SRP1 is fully presented in Barquero, Bosch and Gascón (2013). It was the first SRP experienced by our research team at the university level. It was implemented as a “Workshop of mathematical modelling” along the annual course “Mathematical Foundations for Engineering” for students of Industrial Chemical Engineering. The workshop was aimed to complement the regular lectures and problem sessions with connected activities focused on a vision of mathematics as a modelling activity. Two teachers were responsible for the subject: one preparing the lectures and the other one (first author of this paper) leading the problem sessions and the workshop. The syllabus was organised in a traditional way: one-variable calculus, several variable calculus and linear algebra. The design of the SRP considered this organisation and proposed a longitudinal inquiry starting with the generating question “How can we predict the long-term behaviour of a population size, given the size of a population over some previous periods of time? What assumptions should be made? How to forecast the population size’s evolution and how to test its validity?”. The SRP was divided into three subquestions depending on the assumptions made about the population (separated or mixed generations) and the time (discrete or continuous). In the first part, the forecast question for one population with separated generations motivated the use of numerical sequences, one-variable elementary functions (discrete time), derivatives and elementary differential equations (continuous time) that were introduced in the lectures and worked in the problem sessions in a rather synchronic way. In the second part, the case of mixed generations required tools from linear algebra (transition matrices, discrete time) and of systems of differential equations (continuous time). The workshop was implemented during four academic years. The alignment between the contents of the three instructional devices (lectures, problem sessions and workshop) appeared progressively. During the first ones, the workshop could be seen as an application or illustration of the tools introduced in the lectures and worked in the problem sessions. However, progressively, the workshop started leading the dynamics of the course: its needs were supplied by the lectures and problem sessions as soon as they appeared. We can consider this as an ideal situation in the paradigm of questioning the world: a course mainly based on an inquiry (or several ones) carried out by the students under the guidance of a teacher, the demands of the inquiry being supplied by other forms of knowledge dissemination (lectures, experts’ talks, readings, etc.).

A similar structure was implemented a few years later in the annual subject of Mathematics of a 1st-year degree in Business Administration (SRP2). In this case, all the teachers were members of the research team. Therefore, it was easy to integrate the workshop into the global organisation of the subject. Lectures and problem sessions were not separated. The syllabus was organised in topics (one-variable functions, derivatives, integration, two-variable functions, optimisation, systems of equations, linear applications) and the topics introduced through modelling activities based on business or economical situations (incomes and costs, demand-supply equilibrium, optimisation of benefits, etc.). An SRP was organised during each term and was linked

to one of the main modelling situations of the course as if one of the problems approached in the course was devoted to a more in-depth inquiry. For instance, the first term SRP (one-variable calculus) was proposed from the generating question: “A firm registers the term sales of its seven main products for three years. What amount of sales can be forecasted for the next terms? Can we get a formula to estimate the forecasts? Which are its limitations and guarantees?” In the third term (linear algebra), the generating question was about the managing of a bike-sharing system in Barcelona, considering 3 park locations and the transfer of bikes from one to another. In both cases, one of the three-week sessions was devoted to work on the SRP (in a Modelling Workshop), one week for autonomous group work under the lecturers’ supervision and another to share the results obtained and collectively validate them. An important difficulty found was to organise an SRP for the second term (two-variable calculus) that could start from a question interesting to the students and involving some of the core contents of the term.

SRP3 was implemented considering our previous experience with SRP1 and SRP2. It was initiated by a forecast question about the evolution of the number of Facebook users (Barquero et al., 2017). In this case, however, the Modelling Workshop was run independently of the course content, as a volunteer extracurricular activity that could give students an extra point (up to 10) to their final mathematics grade. The SRP combined online sessions (autonomous work) and face-to-face sessions (sharing results and deciding the new derived questions to follow). The workshops sessions were devoted to students’ presentations and the debate about the questions posed, new questions to inquiry and the models, tools and answers found out.

AN SRP AT THE END OF THE COURSE: “FINAL PROJECTS”

The second modality of integration is to incorporate the SRP at the end of the subject organisation. Of course, this option forces the researchers to reduce some of the activities implemented in the previous organisation of the course content. SRP5 was the first to follow this format: implementing the SRP in the last seven weeks of the semester and leaving a traditional organisation in the first 9. This SRP was implemented in an Elasticity course (6ECTS; 1 semester) in a Mechanical Engineering Degree in an Engineering School in Barcelona. To study the best options to fit the new teaching format, researchers conducted an epistemological analysis of the prevailing epistemology. This analysis revealed two main facts: on the one hand that the analytically solvable problems in this domain were only the ones including ideal situations detached from real workplace activity. On the other hand, the lab sessions were proposed because of the traditional character, and they presented isolated and non-functional knowledge. The SRP implementation initiated by the generating question “How to design (its shape and material) a bike part?” was intended to enable an engineering activity, closer to the workplace tasks and including the finite element method as one of the main mobilised tools. Even if the students only started the SRP at the final part of the course, the SRP was presented at the beginning of the semester, and it was explicitly used as the *raison d’être* of taught knowledge in the traditional

instructional organisation. This organisation caused the contents taught in the classical organisation to be presented as necessary for the SRP. However, once the SRP was initiated, the question became central, and the goal was to provide a suitable solution for the part of the bike while the contents were incorporated within the engineering activity. The SRP was assessed by means of weekly reports to describe the inquiry activity and a final report including the design and justification of the part. This first experience, implemented during the academic year 2014-15, has already been implemented in 5 editions with different generating questions around the design of machine parts. This modality seems to be one of the most sustainable proposals to incorporate SRP because it represents a balance between the two paradigms.

SRP6 and SRP7 followed a similar modality: devoting the last weeks of the course to a final project to be carried out in the form of an SRP. SRP6 was implemented in the subject of Statistics (6 ECTS) for second-year students of a degree of Business Administration. It was organised as a three-week activity carried out by three groups of 30-40 students with a weight of 30% of the final grade. The generating questions of the SRP were linked to two final research projects of a Master in Marketing and a PhD work in the area of Marketing. The three MSc and PhD students were conducting an investigation on consumer behaviour and had prepared a survey to collect data about different issues: Barcelona residents' attitudes towards tourism, streaming TV consumers and employees' competences in service recovery processes. The generating questions of the SRP were related to each investigation and were to be approached through the analysis of the data collected with the survey. Students used all the statistical tools introduced during the course to elaborate a report for the Master and PhD students and present the results in a poster session on the last day of the course. During the sessions, students worked autonomously in teams of 3-4, with some collective activities to share their main results and difficulties with the rest of the teams. They had to present weekly reports to get feedback on the progress of their work. The teachers intervened to propose guidelines for the final reports and posters, to introduce new tools when necessary and to organise the dynamics of the SRP. The effect of the SRP in the global content organisation of the course has appeared this academic year, the teachers proposing an organisation of the subject centred on case studies to be carried out during two weeks (that can be seen as "micro-SRPs") aimed at preparing the future work of the students in the final project. The results of this second edition of the SRP will be presented during the conference.

SRP7 took place during the second quarter of the 2018-19 academic year in a mathematics course of 6 ECTS of the first year of the degree in Marketing and Digital Communities with a group of 70 students with a weight of 15% of the final grade. In the first seven weeks, the course was organised in lectures and problem sessions covering the usual agenda of one-variable differential calculus (families of functions, domains, derivation, limits, etc.). The last three weeks took the form of a modelling workshop with students working in small teams under the guidance of three teachers in sessions with half of the group-class alternated with sharing sessions with the whole

group-class. The generating question was an adaptation of the one proposed by Ruiz-Olarría (2015) on progressive discounts. Starting from a press release on the impact of the marketing strategy of offering progressive discounts on the price according to the volume of purchase, the question was: “Are progressive discounts a good marketing strategy? Each team looked for an online company that offered discounts of this type with a minimum of two purchase tranches, and different questions were asked, for example: What is the final amount when the number of units increases? What percentage of discount is there when the number of units increases? As a client, I am interested in buying 100 or 101 units? And 500 or 501? As an entrepreneur, how much money am I losing? Etc.” In the last session of the course, the teams made a poster presentation in a public exhibition to explain the results to students of upper courses. The visitors could reward the team with the best poster and the best explanation.

A COURSE ORGANISED AS AN SRP

The third modality of integration is to incorporate the SRP to all the sessions of the course. SRP 4 that is presented in Bartolomé et al. (2018) was implemented for the first time in 2016/17 in a Strength of Materials course of the same Mechanical Engineering Degree as SRP5. The epistemological analysis of the prevailing epistemology of the course revealed that the course contents were presented isolated and that the problems proposed were far from real problems, leaving tasks such as the load estimation or geometry definition out of the students’ scope. The question that initiated the first edition was “You are working as an engineer in a company manufacturing slatted-beds. Your company supplies beds to an American client (a chain of motels). Recently, you have been commissioned to provide them with single slatted-beds, capable of supporting the weight of a 120 kg person.” The course – and the SRP – lasted 17 weeks in two 2-hour sessions per week. Sessions were structured into four parts. One to check the status of the project and decide the questions Q_i that were considered relevant to the problem. Questions were distributed among the teams during the second part and addressed in autonomous work in the third part. Finally, in the fourth part, each team presented the answers obtained to the whole group. Students were assessed during their work in class and through the weekly reports submitted to the teacher.

CONCLUSIONS: THE COEXISTENCE OF THE TWO PARADIGMS

Our review describes three kinds of implementations of SRPs in different university institutions. The first modality (SRP1, SRP2 and SRP3) requires creating a specific timeframe to implement the SRP without modifying the previous organisation of the course. In this setting, the first moment of the implementation have little effects on the contents of the traditional course. However, the evolution of the SRP along the course modifies the way knowledge is presented in the lecture-problem sessions.

The second modality incorporates the SRPs at the end of the course (SRP4, SRP6 and SRP7) causing important and faster changes in the traditional structure. The epistemological analysis of the previous organisation of knowledge is crucial to decide how to shorten the time devoted to the lecture-problem structure.

The final modality (SRP7) is the one requiring deeper changes in the organisation. In this setting, the institutional conditions play a crucial role and should involve not only aspects regarding the course but also the support of the university institution, including material aspects such as availability of different spaces and flexibility on the assessment method.

We finish by stating some initial hypothesis regarding RQ1 and RQ2:

- An important fragility on the SRPs implementation exists depending on the teacher being familiar with didactics or not. When non-didactician teachers take the responsibility of implementing SRPs, some constraints become more explicit and specific support seems necessary.
- The implementation of SRPs can be seen as a process requiring deep changes into the didactic contract. Both teacher and students need to accept new roles and responsibilities that take time and effort. Research on new teaching and learning strategies and devices seems necessary at this respect.
- To guarantee long-term incorporation of SRPs, non-researcher teachers need explicit training on the didactic design and on the use of tools to manage and describe the knowledge involved in inquiry processes (Florensa et al., 2019).
- The more integrated the SRP is (such as SRP4 and SRP5), the stronger is the evolution of the taught knowledge. Consequently, a deeper epistemological analysis of the content at stake is needed, together with an explicit description of the new way to organise it.

ACKNOWLEDGMENTS

Funded by the Spanish Ministerio de Economía y Competitividad, MINECO/FEDER, RTI2018-101153-B-C21 and RTI2018-101153-A-C22.

REFERENCES

- Barquero, B., Bosch, M., & Gascón, J. (2013). The ecological dimension in teaching of mathematical modelling at university. *Recherches en didactique des mathématiques*, 33(3), 307–338.
- Barquero, B., Monreal, N., Ruiz-Munzon, N., & Serrano, L. (2018). Linking Transmission with Inquiry at University Level through Study and Research Paths: the Case of Forecasting Facebook User Growth. *International Journal of Research in Undergraduate Mathematics Education*, 4(1), 8–22.
- Bartolomé, E., Florensa, I., Bosch, M., & Gascón, J. (2018). A ‘study and research path’ enriching the learning of mechanical engineering. *European Journal of Engineering Education*, 1–17.
- Bosch, M. (2019). Study and Research Paths: a model for inquiry. In B. Sirakov, P. N. de Souza, & M. Viana (Eds.), *International congress of Mathematicians* (Vol. 3, pp. 4001–4022). Rio de Janeiro: World Scientific Publishing Co. Pte. Ltd.

- Chevallard, Y. (2015). Teaching mathematics in tomorrow's society: a case for an ongoing counter paradigm. In S. J. Cho (Ed.), *The Proceedings of the 12th International Congress on Mathematical Education: Intellectual and attitudinal challenges* (pp. 173–187). Seoul: Springer International Publishing.
- Florensa, I., Bosch, M., Gascón, J., & Mata, M. (2016). SRP design in an Elasticity course: the role of mathematic modelling. In *First conference of International Network for Didactic Research in University Mathematics*. Montpellier, France.
- Florensa, I., Bosch, M., Gascón, J., & Winsløw, C. (2018). Study and Research Paths: A New tool for Design and Management of Project Based Learning in Engineering. *International Journal of Engineering Education*.
- Khalaf, B. K. (2018). Traditional and Inquiry-Based Learning Pedagogy: A Systematic Critical Review. *International Journal of Instruction*, 11(4), 545-564.
- Kuster, G., Johnson, E., Keene, K., & Andrews-Larson, C. (2018). Inquiry-oriented instruction: A conceptualization of the instructional principles. *PRIMUS* 28(1), 13-30.
- Larsen, S. P. (2013). A local instructional theory for the guided reinvention of the group and isomorphism concepts. *The Journal of Mathematics Behavior* 32(4), 712-725.
- Rasmussen, C., Kwon, O. N., Allen, K., Marrongelle, K., & Burtch, M. (2006). Capitalizing on advances in mathematics and K-12 mathematics education in undergraduate mathematics: An inquiry-oriented approach to differential equations. *Asia Pacific Education Review* 7(1), 85-93.,
- Serrano, L. (2013). *La modelización matemática en los estudios universitarios de economía y empresa: análisis ecológico y propuesta didáctica* (Doctoral dissertation). Barcelona, Spain: Universitat Ramon Llull.
- Serrano, L., Bosch, M., & Gascón, J. (2010). Fitting models to data: the mathematising step in the modelling process. In V. Durand-Guerrier, S. Soury-Lavergne, & F. Arzarello (Eds.), *6th Conference of the European Research on Mathematics Education* (pp. 2186–2195). Lyon: Institut National de Recherche Pédagogique.
- Wawro, M. (2015). Reasoning about solutions in linear algebra: The case of Abraham and the Invertible Matrix Theorem. *International Journal of Research in Undergraduate Mathematics Education*, 1(3), 315-338.
- Winsløw, C., Matheron, Y., & Mercier, A. (2013). Study and research courses as an epistemological model for didactics. *Educational Studies in Mathematics*, 83(2), 267–284.
- Zandieh, M., Wawro, M., & Rasmussen, C. (2017). Inquiry as participating in the mathematical practice of symbolizing: An example from linear algebra. *PRIMUS*, 27(1), 96-124.