Interdisciplinary approach to the teaching of technical writing in two technological institutes in Brazil and Norway

Abordagem interdisciplinar para o ensino de escrita técnica em dois institutos tecnológicos no Brasil e na Noruega

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Abstract

The teaching of technical writing to novice STEM researchers in two technological institutes, in Brazil (IFSP) and in Norway (NTNU), has been an interdisciplinary effort that integrates linguistic and technical disciplines, while building on the local context and fostering student autonomy. Within this approach, we use two tools: the career-related *Design Thinking* framework, in a pedagogical application that teaches writing alongside project development for problem-solving (RODRIGUES; BAPTISTA, 2019); and the *Writer's Wheel* (HAAS, 2009), a writing model that guides students to the understanding and management of their own technical scientific writing process. We show how an integrated approach involves drawing appropriately from several disciplines, leading students from convention to innovation, from the development of linguistic, cognitive and technological strategic competence towards autonomy, based on their needs. We find that teaching writing in parallel with project development guides students to understand and manage their own communication process. We outline possible next steps in the improvement of the approach, with regard to theory and educational practice.

Keywords: Interdisciplinarity. Integration. Technical Writing. Technological institutes. Autonomy.

Resumo

O ensino de redação técnica para graduandos das áreas STEM, em dois institutos tecnológicos, no Brasil (IFSP) e na Noruega (NTNU), tem sido um esforço interdisciplinar, na integração entre disciplinas linguísticas e técnicas, considerando o contexto do aluno e promovendo sua autonomia. Nessa abordagem, utilizamos: *Design Thinking*, cujas técnicas para a vida profissional, empregadas pedagogicamente, integram a redação ao processo de resolução de problemas no desenvolvimento de projetos (RODRIGUES; BAPTISTA, 2019); e *Writer's Wheel* (HAAS, 2009), um modelo de escrita que orienta a compreensão e o gerenciamento do processo de redação técnico-científica. Mostramos como uma abordagem integrada envolve a intersecção entre disciplinas, levando os alunos da convenção à inovação, das estratégias linguísticas, cognitivas e tecnológicas à autonomia, para o atendimento de suas necessidades. Descobrimos que o ensino da escrita técnica, em paralelo com o desenvolvimento de projetos, leva à compreensão e gerenciamento do processo de comunicação. Descrevemos os próximos passos no aprimoramento da abordagem, no que diz respeito à teoria e à prática educacional.

Palavras-chave: Interdisciplinaridade. Integração. Escrita técnica. Institutos de Tecnologia. Autonomia.

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1 INTRODUCTION

Learning technical writing for communicating professional projects and scientific research is one of the demands in STEM[1] University courses. However, for students who are new to such a complex academic/professional environment, the context is full of dichotomies. They need to learn how to follow conventions as well as being autonomous for doing and communicating science. In addition, writing is a complex communicative process and science is provisional and interindividual. Both writing and scientific research are processes mostly made of questions rather than answers where theory is surpassed by practice. By the scientific process we mean turning problems into solutions. In other words, by building knowledge. Knowledge comes from information, which is meaningful data. This is the research process communicated through language.

Scientific writing requires the use of technical language, which novice students are acquiring in contact with training in their field and discipline. Students need to understand that, although science is not definitive, the communication of science in technical writing is well-defined. Besides motivation for doing science, students need to become scientists and not only stay scientists, because one's perception of their context can affect the way s/he communicates their practices in this context. Some of the values (and attitudes) for becoming a scientist are obstinacy, discipline, commitment, collaboration and from the latter one has to show vulnerability in order to have the courage to ask for help in their learning process. Students make mistakes when trying to communicate new knowledge produced by a scientific investigation, and professors will evaluate rather than punish them for their first unsuccessful attempts.

Teaching technical writing is quite as complex for language professors as it is for novice STEM University students to learn it. Writing technical documents is an expert's job, but teaching how to do it is a language professors' demand. This is the reason why language professors need to search for ways to build bridges between technical communication and language instruction based on language use. They can then understand the professional context and make their teaching practice useful and meaningful for students as well as help them find discipline and autonomy towards competence and independence.

This is the path we can guide Undergraduate & Master's/PhD students through to an independent professional career. We can offer students cognitive, linguistic and technological tools as well as develop strategies to maintain their involvement and motivation. This is one of the creative aspects of the integrated approach we propose here, which aims to show how we can teach students to follow the necessary conventions of technical writing, but also enable them to innovate when communicating in Academia and in their future working life.

Our starting point is the idea that building awareness of the scientific process underlying technical writing starts from empathy towards novice STEM researchers' autonomy. What are their needs in terms of linguistic competences for being able to follow conventions and communicate effectively with innovation? What kind of skills do they need to acquire and put into practice in order to achieve the expected results,

[1] Science, Technology, Engineering and Mathematics

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which is being able to describe their academic and professional concepts and processes? What are the cognitive skills underlying communication? How can we help them understand and take control of their own writing process so that they can function independently of writing tutors?

From this starting point, we argue that the teaching of technical writing for novice STEM researchers should be an interdisciplinary effort that integrates insights from linguistic and technical disciplines. First, we present relevant aspects of the institutional context and our perception of our students' needs. Next, we show the reader where in the disciplinary landscape we position ourselves and our perspective on technical writing, especially with a view to interdisciplinarity. After setting the scene for where the students are, we will look at the landscapes where professors should be. If we want to lead students from empathy to autonomy, we need to become the kind of professors they need. This can be accomplished from getting to know their needs first and adapt our competencies to the skills they need to develop within the course of technical writing.

2 WHAT ARE THE STUDENTS' CONTEXTS AND NEEDS?

2.1 IFSP CONTEXT

The Federal Institute of Education, Science and Technology (IFSP) is a public Higher Professional Education multicampi institution with schools in every state of Brazil. It offers vocational scientific and technological courses in an integrated curriculum that ranges from Basic Education (High School) and Undergraduate courses (Bachelor's degrees, Technological High Education and Pedagogy) to Master's Degrees in Engineering and in Professional Technological Education. It is a very diverse institution whose mission is to excel at promoting free public professional, scientific and technological education, at all levels and modalities, through the articulation between teaching, research and extension, for the integral education of citizens responsible for a sustainable development of the State and the Region[2].

Technical writing instruction is mandatory in every Undergraduate course and the discipline is offered in the first semester in Engineering. Classes are taught in Portuguese. Novice students to this course come from different backgrounds in various cities around Brazil. The 40-student groups are heterogeneous not only because of their social cultural differences, but also due to the fact that some come from private and others come from public High Schools. Most that come from public vocational High schools have previous technical knowledge in Computing and in assembling industrial projects.

Such diversity has become a challenge for having students and professors find a common ground where to start from. In addition, since the integrated curriculum is a principle underlying every discipline in our context of Professional Technological

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[2] In Sao Paulo state there are 30 campi. The campus of Sao Joao da Boa Vista (SBV) has 15 different courses (Technical Vocational Integrated to High School, Technical Courses, Undergraduate and Graduate Courses) in Business Management, Computer Science, Engineering, Physics, Chemistry, Education and Humanities < https://ifsp.edu.br/institucional>.

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Education, disciplinary intersection is required. Thus three professors have developed an interdisciplinary integrated project called “Communication & Engineering”, in the disciplines Communication for Technical Writing, Introduction to Engineering and Technical Drawing in the The Control and Automation Engineering Undergraduate course (see the disciplines syllabus in Table 1 in the Appendix).

The Control and Automation Engineering Undergraduate course educates students to become professionals in the industry and service sectors and comprises engineering associated with mechanical, electro-electronic and physical-chemical processes. It covers actions for installation, operation, maintenance, control and optimization in processes, predominantly in the industrial segment, but also in research institutions and the environmental and services segment[3]. Far beyond developing the requirements for operational skills, students need to learn how to communicate effectively in order to report their project development in written technical documents.

2.2 NTNU CONTEXT

At the Norwegian University of Science and Technology[4] (NTNU) in Norway, the relevant technical writing course is called Scientific Communication for Engineers[5] (SPRÅK3501). This course is one of several elective options for engineering students who are in the final year of their Master and working on a research project (usually called a Specialization Project or Pre-Master Project; both project types are meant as preparation for the final Master research project).

The students taking the Scientific Communication course are enrolled in different engineering Master programs at NTNU and come both from Norway and from abroad, as regular or exchange students. Although the exact student numbers and distribution of Master programs in the course differ every year, there are certain stable trends. Firstly, when left completely open, the course attracts between 250 and 270 students. Secondly, there is always a wide range of Master programs represented in the course (in Fall 2020 there were 19 different ones, see Table 2 in the Appendix). Thirdly, the number of international students is always substantially smaller than the Norwegian group (and likely to decrease further due to the pandemic-induced travel limitations). Finally, there are always substantial groups from the Industrial Chemistry & Biotechnology, Cybernetics & Robotics, and Material Science & Engineering (also the case in Fall 2020).

This rich course group profile is the source of great heterogeneity. The most obvious source are the disciplinary differences between the Master programs and the nature of the students’ research. While some students work on solutions for a practical, real-life problem, often industry-commissioned (such as building AI systems for the automatic inspection of bridges for corrosion), other students work on purely fundamental research with no immediate practical application (such as describing the nature of a chemical reaction not immediately relevant for industrial application). Another very important source of heterogeneity is the students’ personal characteristics and background (such general maturity, discipline, independence,

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[3] <https://www.sbv.ifsp.edu.br/cursos?id=176>
[4] NTNU has a main profile in science and technology, but also includes the humanities, social sciences, economics, medicine, health sciences, educational science, architecture, entrepreneurship, and art disciplines <https://www.ntnu.edu/>.
[5] <https://www.ntnu.edu/studies/courses/SPR%C3%85K3501#tab=omEmnet>

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learning styles), academic skills and experience (such as experience with research and academic writing skills), and level of ambition (some students take the course mainly to learn, others take it mainly for the credit points). One important aspect in this area are cultural differences – in communication (personal and institutional), educational approach and learning styles, and no doubt a certain culture shock upon coming to a remote and cold place in Norway.

There are also many similarities, which is what brings these students together in this course. Regardless of their specialization, they all need to learn how to communicate their research effectively, especially in writing, and especially through technical and scientific writing genres. And out of these, Project Reports and research-based Master theses are the most relevant at the time of the course, since the students are in the last year of their studies at NTNU. Another very important thing that all students share is the place of the course in their studies: the course is elective and located at the Faculty of Humanities, rather than at their respective STEM faculties. This makes the course and the students' approach to it distinctly different from other more technical courses that are the core of their studies.

Although most students say the course is very useful and better than other elective courses, individual students experience the course differently, have different needs, and value different aspects of the course. Some students see the course as very useful but not challenging enough, and they express a wish for more reading and more scholarly depth in the given topics. Others see the course topics as useful but seemingly too obvious and familiar, which means they tend to underestimate their importance; these students want to be continuously forced to use the acquired skills and knowledge. And, as with any course, there are also students who struggle to keep up and consider the course topics and tasks too challenging. Some want obligatory course attendance, while others appreciate that the course requires less physical attendance than their technical subjects. In sum, the heterogeneous make-up of the course presents a challenge, which needs to be taken into account in the instructors' approach to teaching technical writing.

3 HOW CAN WE ADDRESS THE STUDENTS' NEEDS?

3.1 DEFINING OUR JOINT FOCUS: TEACHING TECHNICAL WRITING

Generally speaking, our joint aim is to teach our students to communicate technical processes and the research they develop in writing through the conventional channels to the relevant audiences, depending on the students' current and (likely) future needs. In the IFSP teaching context students need to write projects, reports, tutorials, in Portuguese, and abstracts in English, and scientific monographs and scientific papers for course conclusion and during their future careers. In the teaching context at NTNU students have to write project reports, scientific abstracts, and research-based Master theses in a range of engineering disciplines during their current studies, and scientific articles and monographs during their future research career, in English and in Norwegian. The two contexts (IFSP and NTNU) are therefore different, and each requires a range of specific context-based genres. However, we recognize that this range of very specific genres shares higher-level characteristics that have the

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same implications for pedagogical practice. In other words, for our joint pedagogical purposes we choose to draw genre boundaries at a higher level, based on shared characteristics (SWALES, 2019).

The range of specific genres relevant in the two contexts (IFSP and NTNU) share the characteristics of *technical writing*. Technical writing is used in technical and occupational fields such as computing, engineering, chemistry, finance, medicine and many others. It is traditionally seen as a verbal production skill focused on particular types of structure and style. As for content, it communicates complex technical information in manuals, tutorials and articles. As for its communicative aims, technical writing aims to develop, gather, and disseminate technical information to researchers and to user groups (such as customers, designers, and manufacturers). The term *technical writing* is therefore used here as an umbrella term for the type of writing taught to novice STEM researchers in the two contexts (IFSP and NTNU).

In research and teaching, technical writing can be addressed from a range of perspectives, using slightly different lens on conventional text structure; and we draw on these different perspectives to provide students with useful linguistic, cognitive, and technological tools. For example, English for Academic Purposes (FLOWERDEW; PEACOCK, 2001) tends to focus on academic, formal vocabulary (single words), phraseology (combination of two or more words), grammar structures, and sentence structures. This approach is manifested in useful online resources such as the Academic Word List (COXHEAD, 2011), Using English for Academic Purposes (GILLET, 2005) and the Manchester Academic Phrasebank[6] (MORLEY, 2004). Next, rhetorical genre analysis focuses on a higher level of textual organization, namely rhetorical moves that are characteristic of research papers written in English. Here, the conventional IMRaD[7] (WU, 2011) and CARS[8] (SWALES; FEAK, 2009) are valuable tools for the analysis and for the teaching of the structure of scientific articles; and the MAZEA-web tool[9] (DAYRELL et al, 2012) breaks down abstracts into rhetorical moves, which helps authors see whether their abstract matches the conventional structure. Finally, Scientific Research Writing tends to bring these partial aspects together and provide a holistic style-guide, as it were. A good example of this approach is Cargill and O'Connor (2019), whose book provides concrete steps to writing scientific research articles. These theoretical approaches and (technological) tools can be used in combination, and many overlap to some extent: compare for example Swales' rhetorical moves and language functions in the Manchester Academic Phrasebank.

The central concern of these approaches is in the scope of academic style and text genre concept (JORDAN, 1997): students need to learn the conventional text format to achieve a clear structure and a tuned style for writing technical text genres. Also, they need to grasp the linguistic framework within such a format in order to use the language patterns, the phraseology needed to communicate to a specialized audience. However, besides acquiring knowledge on academic/technical text genre composition and style and linguistic skills as word choice and sentence structure, students also need to develop cognitive skills such as critical thinking for logical reasoning and problem solving. Text genre knowledge implies awareness that both the

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[6] <http://www.phrasebank.manchester.ac.uk/>
[7] Introduction, Method, Results, and Discussion (IMRaD) corresponds to the ABNT manuscript format of technical documentation in Brazil (<http://www.abnt.org.br/normalizacao/lista-de-publicacoes/abnt>)
[8] Creating a Research Space (CARS)
[9] <http://143.107.183.175:15080/mazea/>

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compositional aspects of academic/technical writing and the language style are conventional because communication is shaped by the specialized audience. Although a great amount of jargon is used, academic/technical writing is entailed to clear communication of direction, instruction, or explanation.

Therefore, we argue that any one of these perspectives alone cannot capture the full complexity of academic/technical writing; and that the teaching of technical writing to novice STEM researchers needs to be an interdisciplinary effort, which integrates linguistic approaches, technological tools and an understanding of the cognitive principles underlying the process of written communication.

3.2 TOWARDS AN INTERDISCIPLINARY APPROACH TO TECHNICAL WRITING

One way of achieving an interdisciplinary approach through integration is to teach technical writing through project development (VALERIANO, 1998); in other words, teach students how to write in parallel with teaching them how to develop a project. Project development is the process of planning, organizing, coordinating, and controlling the resources to accomplish specific goals. The process takes a transportation improvement from concept through construction[10]. When we model technical writing dynamically as a process (MEMIŞ; ÖZ, 2014), and in parallel with project development, we come up with a higher (cognitive) narrative. The higher narrative of scientific technical communication is <Problem – Solution>. This cognitive narrative approach (HERMAN, 2003) can take students beyond manuals of formatting and style and can work as a toolbox for innovation. This does not mean that students can change convention, but they can be creative while thinking of the content which is going to be communicated conventionally. This will assist them in understanding, describing and communicating complex concepts and processes as they visualize a schemata (PRITCHARD; HONEYCUTT, 2006) of their investigation walking from a source (finding a problem) through a path (choosing methodology) towards a goal (finding a solution).

A concrete example of such an approach is the Integrated Project "Communication & Engineering" at IFSP, which has been put into practice by three professors – a linguist and two engineers – to intersect two technical disciplines (Introduction to Engineering and Technical Drawing) and the discipline Communication for Technical Writing. Students are in the same grade and course in different disciplines, which are integrated from disciplinary intersections. The project comprises teaching and learning that articulate the interdisciplinarity of the curriculum with research and extension actions in order to allow the construction of knowledge, culminating in an academic and technical-scientific production. Students need to write the sections of a technical-scientific project, a video script for a product simulation and Powerpoint slides for an oral presentation. It starts from choosing a theme within the scope of the course/the career and next finding a problem to be turned into a solution through the employment of feasible methods. As there is a scientific process underlying technical communication, we scaffold the technical writing process in a way that stimulates both cognitive/thinking and communication/linguistic skills. It requires critical thinking and decision-making skills for discussing and questioning ideas

[10] <https://www.igi-global.com/dictionary/theme-scenario-development-in-interior-architecture/47429>

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fluently, based on evidence, creative thinking, reasoning and logical inference (MEMIŞ; ÖZ, 2014), and also two kinds of knowledge: knowledge of the topic and knowledge of text genre (MCCUTCHEN; TESKE; BANKSTON, 2008). The project is carried out as part of the Control and Automation Engineering Undergraduate course, which aims to develop competencies and skills related to teamwork, self-learning, communication, negotiation, decision making, problem solving, critical thinking, organization, leadership, planning; professional ethics and responsibility; administrative, economic, business management; projects and analysis of environmental and social impact[11].

The Integrated Project showcases the integration of cognitive principles of communication, linguistic approaches and technological tools. Firstly, critical thinking for both problem-solving and knowledge of the topic development is stimulated by having students read technical literature and discuss their ideas with the expert in the field, namely the two Engineering professors. Secondly, the knowledge of the text genre is linguistic and is used to describe and discuss technical concepts and processes as students learn to structure topic content through the structure <Introduction – Methodology – Analysis & Results – Discussion & Conclusion>. For some of these sections, students use a more declarative and for others a more argumentative language. Choice of words and sentence structure differ as they either describe the steps of product development or procedures of material use, for example, or as they discuss results from data analysis. As for the display of the Project Development timeline and of the budget, students need to use visual language to create tables and graphs. Throughout this path, Design Thinking tools (LIEDTKA; OGILVIE, 2011) are used to create a parallel between Project Management and Writing as a learning process. We picture writing not as a linear process leading to a definite product, but as a recursive and dynamic tool, which takes stages such as prewriting, writing and rewriting (PRITCHARD; HONEYCUTT, 2006) towards a text, which is a well-defined product. Design Thinking works as a leverage point that links theoretical frameworks from various disciplines and uses study design and methodology of different fields.

The perspectives and skills of the involved disciplines are used throughout multiple phases of the teaching process. The main opportunities are the overlaps among the three disciplines, which demand communication of technical processes in the field of Engineering for writing scientific technical documents, such as projects, reports and papers. It requires conventional linguistic communication as well as creative visual language use. In addition, critical thinking for problem-solving and decision making in group work require the development of skills. This interdisciplinary approach is thus not limited to any one field, but it is based on intersections from two or more distinct disciplines, which work together to create new conceptual, theoretical, methodological and translational innovations that integrate and go beyond specific approaches to address a common problem (ABOELELA et al, 2007). It is about how language skills in the Communication for Technical Writing discipline help develop technical scientific skills in Technical Disciplines and vice-versa.

This integrated curriculum is thus framed as a principle underlying all the disciplines and it implies integral human education, considering humans in their omnilaterality, in a holistic and totalizing perspective. It is also linked to work as an educational principle, in order to articulate the knowledge experienced at school with

[11] <https://www.sbv.ifsp.edu.br/cursos?id=176>

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the world of work[12]. From this perspective, according to Freire (1996), education is not the mere transmission of content from teacher to student. Knowledge is built collectively when students become critical active subjects in their own learning process. Autonomy is developed based on innovative approaches that integrate theory and practice and thus contribute to transform reality.

4 HOW CAN WE HELP STUDENTS SUCCEED ON THEIR OWN? TOWARDS STUDENTS' AUTONOMY

4.1 DESIGN THINKING TOOLS FOR TECHNICAL AND SCIENTIFIC WRITING IN PROJECT DEVELOPMENT

In order to guide students from Academia to Professional life while preparing them for written technical communication, we develop strategic competence towards autonomy. Professors can provide students with opportunities to deal with scientific technical written communication challenges, going from simulation to inspiration in an Integrated Interdisciplinary Project now at the university, involving them as “managers” and “designers”. Next, when students need to develop a Research Project, still at the university, professors will become advisors of the now autonomous research students. In the future professional environment, in an Engineering Project at a company, students become autonomous workers. By projecting these experiences throughout time and in different spaces, students are able to develop lateral thinking and thus create innovation.

At IFSP *The Design Thinking tool* (RODRIGUES; BAPTISTA, 2019) is used as Pedagogy to work with Project Development and it goes from teaching and learning to working. The professors’ pedagogical integrated project serves as a role model for professional projects (or vice-versa) intertwined by scientific research practice in the three stages of knowledge construction, from data to information and then to knowledge. It works for students’ as a simulation of “real life” happening at school. Design Thinking is a creative and learning process, usually used to tackle complex problems by focusing on users and their needs. The design process is based on the “building up” of ideas (LIEDTKA; OGILVIE, 2001). The building up of ideas is a complex process where different needs can converge: Communication has a Human & Social approach whereas Technical Drawing is very technical and Introduction to Engineering is a blend between Human & Social and Technical approaches. The blend also happens between Management and Education, where the “designers” are the professors and the tool is pedagogy. The Integrated Project is made up of three stages: planning, implementation and evaluation (Figure 1).

Pedagogical planning starts with an EXPLORATION stage, in which designers/professors resort to their questioning skills to pay a close attention to what is going on so as to find a problem or necessity to tackle. After identifying and defining the problem, designers initiate PATTERN-FINDING, a stage in which they brainstorm possible answers to the question, by imagining possible ways to solve the problem. It requires imagining skills to envision where insights could be translated into new possibilities. The third stage in the design process is IDEATION, in which they move

[12] <http://www.sites.epsjv.fiocruz.br/dicionario/verbetes/curint.html>

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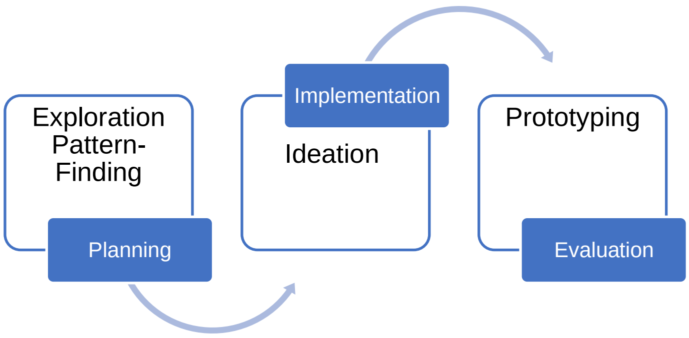
from a hypothesis-generating mode to a testing mode. It is implementation in pedagogical terms. This is the stage where they resort to their testing skills to experiment and test the assumptions underlying each hypothesis and make some choices. Finally, the fourth stage is PROTOTYPING, in which they activate their creating skills to offer a prototype of their idea out of the evaluation of the project itself based on the evaluation of the students (RODRIGUES; BAPTISTA, 2019 based on (LIEDTKA; OGILVIE, 2001).

Figure 1: Project Pedagogy mapped in terms of Design Thinking Tools



Source: Own Construction

In the planning stage (Table 1), an Institutional Project is written and submitted to the IFSP-SBV Director of Studies in order to describe the demand and the purpose, the activities and the schedule, and the benefits of the proposal. Once approved, a Pedagogical Contract is established with students. Next professors work on the integration of Disciplines Schedule, Material Development and Evaluation Criteria. Moodle is used as the Learning Platform.

Table 1: Planning as Elaboration and Pattern-Finding

PEDAGOGICAL STAGE	DESIGN THINKING STAGE	ACTIVITIES
Planning	Exploration	Institutional Project approved Pedagogical Contract with students
	Pattern-finding	Disciplines Schedule Material Development Evaluation Criteria Class material set up on Moodle

Source: Own Construction

For Implementation (Table 2), during the classes of the three disciplines throughout a semester, students are assigned roles in group work (technical, communication, research and finance) and a general theme and subtopics for the

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groups are defined after discussion and decision-making (they map their context problems and demands). The themes worked on in the past three years of the Project were Sustainability, Innovation and Accessibility at school. The next step is to start developing the project weekly: narrowing the theme, finding a gap, setting the purpose, choosing methods, working on results and discussion, presenting a conclusion. The tasks are: literature review (information literacy: online database & Boolean operators); scientific writing (logic elements: variables & association with/out interference); kinds of method (techniques with the use of tech tools); schedule & budget for feasibility; data analysis (interpretation); directions out of conclusions; ABNT[13] formatting guide. Throughout this stage, students are guided through the use of technological tools such as online glossaries and dictionaries as well as a visual thesaurus <https://www.visualthesaurus.com> to help build technical repertoire and clarify jargon, and also writing tools to assist them with the conventions of manuscript formats and phraseology of text sections <http://www.escritacientifica.sc.usp.br/scipo-farmacia/eng/>.

Table 2: Implementation as Ideation

IMPLEMENTATION / IDEATION	ACTIVITIES / SKILLS
Communication for Technical Writing	Reading technical scientific literature Writing the sections of the document
Introduction to Engineering	Theme narrowing and topic choice Assignment of roles in Group Work & Group Work Management Discussing feasibility and cost-benefit Interpreting gaps to establish goals Interpreting results to find conclusions
Technical Drawing	Schedule & Budget Design Method scope and design ABNT formatting style

Source: Own Construction

The Evaluation (Table 3) consists of the presentation of a written document, which is a technical-scientific project. Before producing this final document, students work on method simulation displayed in a video so that the Engineering professors can validate its feasibility and cost-benefit from a budget and a schedule. When the final document is ready, students present the proposal in a seminar. The video, the written project and the seminar are graded according to each discipline purpose. As for the evaluation of the Integrated Project itself, students answer a questionnaire in an electronic form about what they have learned in terms of skills and attitudes and content knowledge in the three disciplines.

[13] < http://www.abnt.org.br>

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Table 3: Evaluation as Prototyping

EVALUATION/PROTOTYPING	ACTIVITIES/SKILLS	PEDAGOGICAL PRODUCTS
Communication for Technical Writing	Writing skills Knowledge of text genre (technical scientific project) Use of language (grammar and vocabulary)	Video Written technical-scientific project Seminar
Introduction to Engineering	Research Skills Knowledge of the topic Budget and schedule feasibility	Video Written technical-scientific project Seminar
Technical Drawing	Technical skills Formatting & Normalization Use of visual aids (technical drawing of the products)	Video Written technical-scientific project Seminar

Source: Own Construction

The feedback from professors, from classmates and from self-reflection is beneficial for raising the autonomy students need when they "become" professionals or academics, although many choose to only "stay" professionals or academics while in college. They learn not to be entirely dependent on professors, as they have to rely on group work and on building their own knowledge from disciplinary intersections. They become creative protagonists from the time they are allowed to choose a theme and find a problem within a relevant topic and turn it into a solution by developing valid, reliable and practical methodology. Every week, the language professor gives ongoing feedback over the three stages of writing: encouraging drafts as prewriting; presenting writing models from templates and examples while writing; and using peer feedback and revising bits of text so that they can rewrite them.

Besides giving students a sense of organization and progress, this approach serves as a role model/a case for tackling a common problem through the integration of complementary expertise under lateral thinking techniques, which will bring a diverse point of view. Professors have the demand of teaching/monitoring students in project development and they use Design Thinking Tools as Pedagogy, by blending Project Management and Education. This can work as a meta-activity for students as they can learn to map their scientific research as a design thinking process as students. In the future as engineers they will have to learn how to solve problems for Project Management.

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4.2 THE WRITER'S WHEEL: A DYNAMIC MODEL OF THE WRITING PROCESS

One of the most useful tools for fostering autonomy used in the NTNU context is the Writer's Wheel (HAAS, 2009). This is a dynamic writing model based on a collaborative co-construction of the writing process in a group of students and their teacher-researcher. The model is composed of *Modes* (which can be understood as stages in the writing process) and *Moves* (the ways in which the stages are carried out). Since the model is compiled bottom-up, through brainstorming, elicitation, and reflection by learner-writers themselves, it gives a more accurate and useful perspective on the writing process than models designed top-down by researchers and for researchers[14] (HAAS, 2009). At NTNU the model is used to help students understand their own writing process and to take control over it rather than "be controlled" by the process (HAAS, 2009) so that their writing experience is more positive and productive. Additionally, the model is also conceptualized as a powerful framework for giving feedback to students on their writing progress.

The model is typically introduced in a practical small group session which is part of the NTNU Scientific Communication course. The session is student-centered and loosely follows Haas' brainstorming procedure (although Haas does not use this label, she does, in fact, meticulously follow the divergent and convergent stages of brainstorming). First, students are asked to recollect the writing they have produced so far (such as essays, reports, abstracts, lab logs, etc.). Depending on the teaching setup and classroom arrangement, this can be run as a brainstorming session, where the teacher/instructor records examples of the writing products on a whiteboard or blackboard, so that they are visible to everyone. Next, students are asked to reflect on the process they typically go through when they write (such as identifying and narrowing down a topic, planning an outline, drafting, re-writing, but also procrastinating, and being stuck). Here, they quickly realize that their "writing process" includes many activities that do not involve producing text, and that "writing" is interrelated with research. This type of reflections and insights is a good sign – it shows that students are not thinking in terms of pre-existing top-down writing models but in terms of what they actually do. It also shows that students are well aware that "doing research" and "writing up research" are not separate processes.

Finally, students are presented with the "Writer's Wheel" (HAAS 2009, p. 28) and asked to compare their reflections described in the model. Do the parts or stages of their own writing process align with the *Modes* and *Moves* in the model? Here, students typically identify modes such as *Structuring* and *Polishing*, which can reasonably be expected to appear in anyone's writing process. Does the model contain any stages they do not recognize from their own experience? This usually leads to discussions of the order of different activities (moves): for example, some students start writing by top-down planning and outlining, while other students may by free-writing. Is there anything surprising and eye-opening in the model? Here, two Modes are invariably listed by the students: *Incubating* and *Unloading.* This is not surprising, either: Haas points out that these two modes are typically not present in formal writing models, because they represent the seemingly messy part of writing and thinking. They capture activities that are often seen as undesirable: *Incubating* does not involve

[14] Bottom-up and top-down approaches are described here < https://en.wikipedia.org/wiki/Top-down_and_bottom-up_design>.

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producing text (which may suggest lack of discipline or delay), while *Unloading* typically involves producing unstructured, incoherent, unpolished text (which suggest lack of skills, discipline, or organization). However, these two modes tend to be the most profound contribution of the model: students feel liberated (from what they "should be doing" according to formal models) and acknowledged (in that these are legitimate and necessary parts of the writing process).

Students are then encouraged to actively and independently use the model whenever they have to write something. They are asked to reflect on where in the Model they feel they are at a particular moment, and what they are currently doing. Are they in the *Exploring Mode*, carrying out activities such as *Finding a topic, Reading, Taking notes*? Or are they in the *Structuring Mode*, which may mean *Outlining* or *Drafting*? Or are they in the *Incubating Mode*, when they don't feel ready to put text on the page yet? What other activities might move their writing forward at this stage? Are they ready to move into the next stage? Haas' model is dynamic and can easily be adjusted to individual needs. The circular nature (Wheel) is meant to suggest that a writer might start their process anywhere in the model, not necessarily by reading, as might be expected (the pre-writing stage in traditional writing models). For example, some writers like to start by free writing in order to gain understanding and focus of their topic. Other writers do like to read and think extensively first (but even that will typically include some writing – such as taking notes, and those need to be structured, etc.).

This dynamic model also provides a powerful framework for instructor feedback, and helps students understand the nature and function of feedback. In the NTNU context students tend to expect instructors to *assess* their text in a summative manner; and they expect to see comments on or corrections of *all* textual aspects, from global organization to grammatical markers. What students then do with all this feedback, and how they act on it, is a different matter. Many do not act on feedback and are simply content to see that the teachers have invested a great deal of effort in grading their texts. This attitude to feedback does not serve students well as it causes unnecessary anxiety about drafts as in the Norwegian context drafts are referred to as *unfinished text* (uferdig tekst) (JONSMOEN; GREEK, 2012) and it creates the impression that all aspects of a text matter at all stages of writing. Haas' model helps instructors reframe feedback as helping with aspects of text that are relevant in the current writing stage. For example, when students are in the *Structuring* or *Unloading* mode, instructors focus their feedback on the content and structure; but when students are in the *Polishing* mode, instructors zoom in on aspects such as academic vocabulary and phraseology, concise formulations and grammatical accuracy. The use of Haas' model in the NTNU context is helping students embrace feedback as an opportunity not only for the development of writing skills but also for the independence of the instructor and student autonomy.

To sum up, this dynamic and organic model of the writing process is a useful tool for fostering autonomy in students and helping them become independent writers. Firstly, they learn to reflect on their own functioning and learn to identify useful insights and have meta-level discussions with their peers and their instructors. Secondly, they learn to act on these insights and manage their own writing process, without constant input from an instructor/supervisor. Thirdly, they learn to view feedback from instructors as situation-dependent and formative, rather than universal and summative. And finally they shake off at least some of the common writing-related fears and reframe them as a natural part of the writing process, which serves to push their writing further.

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5 CONCLUSIONS

Science is the means to produce new knowledge and aims to break paradigms, revealing the new, proposing solutions and transforming the natural and social world. Moreover, languages build bridges to every field of knowledge as they are the human tool for communicating ideas and conveying meaning. The communication of scientific findings is crucial and is usually done through the publication of technical documents. While language disciplines can themselves play a key role in the teaching of scientific/technical communication, linguists and writing instructors still need input from technical STEM disciplines to help novice STEM researchers communicate their research effectively to target audiences. In this joint process, autonomy - in doing and communicating research, as well as in understanding and managing the writing process - naturally derives from integration and interdisciplinarity. In this paper, we have shown how this interdisciplinary integration of linguistic and technical disciplines for these purposes can be conceptualized in theory and realized in practice.

We have presented concepts and tools for working on text macrostructure and research logic categories paired up with the design thinking stages as well as shown the writers' wheel as a model for writing. We find that teaching technical writing in parallel with professional project and research development guides students to understand and manage their own communication process. One example of such development is organizing students in project groups for concrete assignments that can be carried out autonomously on their own terms (such as oral-visual presentations of own research, or peer feedback on written drafts), setting up joint learning projects using concrete online tools for technical writing (such as the MAZEA-web tool), and designing assignments that help students reflect on, document, and steer their own writing progress. Besides providing students with linguistic and technological tools, our teaching practices have shown them the cognitive principles underlying language - how to deal with complex problems by integrating apparently different, but actually diverse and complementary skills, such as technical expertise, language use, academic conventions, writing.

We plan to do further work on this interdisciplinary integrated approach, especially within the framework of Cognitive Linguistics, developing concepts such as blending (FAUCONNIER; TURNER, 2002) and conceptual framing (FILLMORE, 1982) as tools for creativity. This theoretical approach will help deepen the idea that scientists can innovate in communicating the content of their research, by developing and describing concepts and processes creatively, but still by keeping up with following the necessary/recognizable conventional academic formats.

In addition to further developing the Cognitive Linguistics theoretical framework, we also plan to increase our focus on pedagogical procedures and digital learning platforms, in order to secure student motivation and interaction. In the current pandemic times, with next to zero in-person teaching, we have been making use of Zoom, MS Teams, Blackboard (NTNU) and Moodle (IFSP). While some tools have been established well before the pandemic, others have been more or less emergency solutions. As a result, the interactive parts of our courses, such as classroom discussions, pair- and group work, joint presentations, have been difficult to maintain

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and monitor. Under such conditions there is a danger of decreased student motivation and increased fallout. Therefore, we aim for continuous improvement of course design (such as detailed didactic procedures) and infrastructure (such as digital learning platforms).

To conclude, we argue that an interdisciplinary integrated approach grounded in the local context is necessary and pedagogically viable for teaching technical writing in STEM courses. Linguistic approaches and technological tools are often combined in an eclectic way, as is the case at NTNU, where the make-up of the student group and their needs is diverse, with students coming from different disciplines to take an elective course. We argue that, where the context allows it, such as the case at IFSP, a full integration, in a blend of professional and pedagogical approaches, provides a framework for project development in language classes. Our approach can help teachers reflect on how Linguistics as a science and the cognitive principles applied to it can play a key role in languages disciplines within technological professional education. It promotes a humanistic integral education, as it can help students develop communication not only for their specific technical purposes but for autonomy in their professional life.

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