

Popularization writing education: The effect of explicit instruction on metacognitive awareness in undergraduate interdisciplinary students

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ABSTRACT

In this study, we report on the effect of explicit instruction in popularization discourse on metacognitive awareness in undergraduate interdisciplinary students. We developed a popularization discourse teaching intervention using educational design research. The iterative design cycle lasted four academic years and spanned eight consecutive designs. Then, interdisciplinary students took part in the four-hour in-class intervention. Data from questionnaires and self-reflections were analyzed quantitatively, using a Wilcoxon signed-rank test, and qualitatively, using thematic analysis. The quantitative analysis shows an increase in declarative knowledge and some increase in procedural knowledge. The qualitative analysis shows students have attained declarative knowledge about popularization as a genre, procedural knowledge into how to produce popularization discourse, and self-regulation by managing expectations of popularization writing. One session in popularization discourse could thus already positively influence metacognitive awareness, but more and consistent training would create more beneficial outcomes.

KEYWORDS

Metacognitive awareness;
Student perspective;
Writing skills;
Popularization;
Interdisciplinary
education

Introduction

For results from academic research to make an impact, communication is key. For academics, traditionally, the obvious choice to create impact is academic discourse in the form of journal articles or conference presentations. Yet it is popularization discourse, i.e., science communication or science journalism in the form of newspaper articles, TED Talks, podcasts, SciArt, or TV appearances, that is paramount for creating societal impact for new academic insights.

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Generally, the main goals of science communication are scientific literacy, public awareness and understanding of science, social acceptance and political support of science, funding for new projects, and encouragement of citizen science (Burns et al., [2003](#); Kappel & Holmen, [2019](#)). Communication to a non-expert audience thus forms an important part of any academic career. In the Netherlands, there is a push from the Ministry of Education, Culture and Science and from the Royal Netherlands Academy of Arts and Sciences (in Dutch: KNAW) for science communication to be considered as part of academics' official responsibilities (KNAW, [2022](#)).

Training is one way in which more attention can be paid to the importance of science communication skills for academics. The evaluation of education in popularization as part of university training has shown positive results. Graduate educational programs in science communication teach skills than can be applied in a multitude of careers, such as communication skills, writing skills, teamwork, and public speaking (McKinnon & Bryant, [2017](#); Mellor, [2013](#)). The impact of training on researchers at universities shows that the more popularization training they receive, the higher their inclination is to engage with a broad audience (Copple et al., [2020](#)).

Training in popularization equally benefits the many students who choose not to pursue an academic career. Studies into undergraduate and graduate training in science communication have shown training leads to the development of the transferable skills of time management, project management, and managing a research team (Kuehne et al., [2014](#); Yeoman et al., [2011](#)). This also includes inter-professional skills (Halpern & O'Rourke, [2020](#)), for example collaborating with communication professionals to draw up a press release, which is a form of transferable collaboration skills. Popularization skills can also aid the development of academic skills and scientific literacy (Bankston & McDowell, [2018](#); Parkinson & Adendorff, [2004](#); Pelger, [2018](#); Pelger & Nilsson, [2016](#)).

Thus, acquiring popularization skills is beneficial for higher education students aiming for either a career in academia, or a professional career. But while multiple graduate programs are offered to teach students to become science journalists or science communicators, most undergraduate programs and dedicated disciplinary graduate programs do not offer (consistent) training. Consequently, the effects of popularization education are also underexplored in the academic literature (see Sterk et al., [submitted](#)).

Literature review

In this study, we focus on how explicit instruction in popularization discourse influences metacognitive awareness about popularization writing skills in undergraduate interdisciplinary students. In this section, we elaborate upon the theoretical framework of metacognition and show the existing insights in metacognitive awareness connected to popularization education.

Metacognition

Flavell coined the term metacognition and defined it as “cognition about cognitive phenomena” ([1979](#), p. 906). In other words, metacognition is “knowledge about and regulation of one's cognitive activities in learning processes” (Veenman et al., [2006](#), p. 3). Flavell ([1979](#)) described the interaction between metacognitive knowledge (knowledge

about cognitive processes) and metacognitive experiences (experiences pertaining to cognitive enterprises) together with goals (objectives of cognitive enterprises) and actions (strategies, either cognitive or meta-cognitive, to achieve goals).

Newer views define metacognition as the combination of metacognitive knowledge (declarative knowledge about knowledge, skills, and strategies) and metacognitive skills (procedural knowledge for problem-solving and learning) (Veenman et al., 2006), metacognitive knowledge (declarative, procedural, and conditional) and self-regulation (Harris et al., 2009), or knowledge (information connected to particular cognition), monitoring (observation of the progress of cognitive processes), and control (cognitive control informed by metacognitive knowledge and monitoring) (Serra & Metcalfe, 2009). Conner (2007) stated that the use of metacognition supposes awareness of the learning process and conditional aspects, as well as reflective abilities. Metacognition is tied to academic performance, as it enables students to self-regulate learning and to apply strategies in learning (Brown, 1994; Paris et al., 2001).

Metacognition is also an important factor in writing and writing skill development: “writing is applied metacognitive monitoring and control” (Hacker et al., 2009, p. 160). Hacker et al. (2009) proposed an adaptation of Nelson and Narens’ model of metacognition to make it applicable to the writing process. The object-level of this model contains planning, production, and revision of text as well as reading and re-reading or reviewing; the meta-level contains meta-procedural and meta-declarative knowledge. Harris et al. (2009) divide metacognition in writing into two main components: metacognitive knowledge and self-regulation. Metacognitive knowledge consists of three types of knowledge: declarative knowledge, procedural knowledge, and conditional knowledge. Declarative knowledge refers to knowledge, skills, and strategies that are needed to successfully complete a writing task, such as knowledge about writing goals, the intended audience, genre constraints, and linguistic structures. An understanding of the writer’s own level of proficiency is also part of declarative knowledge. Procedural knowledge is knowledge about the application of actions and strategies in planning, text production, and revising. This also includes genre-specific strategies. Conditional knowledge is used to determine under what circumstances declarative and procedural knowledge should be applied, in other words, the knowledge needed to match skills and strategies to a writing task. The second main component of metacognition is self-regulation, which refers to all activities that regulate the writing process such as planning, monitoring and evaluation.

Metacognition in popularization training

The role of metacognition is more elaborately researched in academic writing than in popularization writing. For example, Negretti (2012) analyzed students’ metacognitive awareness related to academic writing. They found metacognition is a mediating factor between task perception and self-regulation that helps students adapt their writing strategies to the writing task at hand. Moreover, Conner (2007) concluded that students who use metacognitive strategies produce higher quality academic essays. Yet in the research field of science communication, metacognition is only touched upon explicitly from the perspectives of communication effectiveness and risk perception (see for example Bullock et al., 2019 or Huang & Yang, 2020).

Some studies do touch upon student perspectives or student perceptions related to science communication, which could indirectly be linked to metacognition. A study by Mercer-Mapstone and Matthews (2015) concluded that undergraduate science students believe communication skills to be important in their study and future career. A study by Akin et al. (2021) showed that perceptions of science communication self-efficacy do not influence time and effort invested in science communication training. Sense of self-efficacy was not correlated with science communication knowledge before a science communication workshop, but was correlated with it afterwards, showing a positive effect of science communication training. Suprpto et al. (2021) focused on the learning experiences of both students and teachers that took part in a science communication course and showed mainly positive attitudes connected to the role of the science communicator and the course itself. Brownell et al. (2013b) showed practice in writing and receiving feedback improves students' confidence in communicating science and their self-perception of the ability to write popularized articles.

Other studies focused on the effects of training. Training leads to an increase in students' self-report of explanatory skills, communication skills, and sense of being informed (Crone et al., 2011). Training also leads to an increased ability of broader impact writing and communicating to a broad audience, as well as increased feelings of preparedness for this type of writing (Heath et al., 2014). Students see an improvement in their competence (Latimore et al., 2014), ability in communication skills, confidence in popularized communication, skills development and attitude (Mercer-Mapstone & Kuchel, 2016), confidence levels in science communication ability, and confidence to submit popularized writing (O'Keeffe & Bain, 2018). Training also helps students understand the usefulness of communicating science to a non-expert audience or to realize the difficulty in writing to non-professional readers (Moni et al., 2007). Working on a science communication writing assignment had a positive effect on students' perceived understanding of subject matter and its relevance outside of academia, and on their perceived communication skills and attitudes (Finkenstaedt-Quinn et al., 2022). The reverse is also true: undergraduate biotechnology students who had minimal popularization training available to them consequently had little understanding of the theory of science communication and little regard for training in these skills (Edmonston et al., 2010).

These studies focus on knowledge, skills, and attitudes connected to popularization skills, but do not frame them as metacognition. Thus, to our knowledge, metacognitive skills and knowledge are never explicitly discussed in relation to popularization education in higher education. The present study focuses on metacognition connected to writing education in popularization texts. The research question is: *What metacognitive awareness about popularization writing skills do undergraduate students display as an effect of explicit instruction in popularization discourse?*

We follow the definition from Harris et al. (2009) and measure metacognitive awareness by looking at declarative knowledge, procedural knowledge, and self-regulation.

Materials and methods

In this section we outline the set-up of this study, in which we used an in-class intervention in popularization discourse writing to gauge undergraduate students' metacognitive awareness.

Methodological framework

We used educational design research (EDR) as an overarching methodological-theoretical framework. EDR is used to explore educational challenges, design interventions, evaluate that intervention, and disseminate results (McKenney & Reeves, 2019). Sterk et al. (2022) explored the broader educational setting that this study is part of, while this paper focuses on the evaluation phase. In EDR, research is performed for interventions, on interventions, or through interventions (McKenney & Reeves, 2019, p. 23). We conducted research through an intervention, meaning we focused on how explicit instruction influenced metacognitive awareness in students, rather than testing the effectiveness of the educational materials themselves.

Target group

Participants for this study were 77 students in the latter stages of an interdisciplinary undergraduate program at a Dutch university. Their program consisted of liberal education and interdisciplinary training. Liberal education combines broad learning, i.e., “general education”, with a major in one specific discipline (AAC&U, n.d.). Interdisciplinary training teaches students to solve complex, real-world research problems by combining insights from multiple disciplines into one more comprehensive understanding (Klein, 2010; Repko & Szostak, 2021). In their program, participants chose a disciplinary specialization and took part in 30 EC general education and 30 EC interdisciplinary research skills.

The intervention was part of an advanced undergraduate course in interdisciplinary research skills in which students wrote an interdisciplinary thesis in multidisciplinary teams of three or four. The goals of the course were learning to set up, conduct, and evaluate an interdisciplinary study; collaborate in a multidisciplinary team; and communicate insights from the interdisciplinary study to a non-expert audience. The course consisted of four plenary sessions consisting of four hours each, four team feedback sessions with an interdisciplinary advisor, and two individual feedback sessions with a disciplinary advisor.

A difficulty that students who are learning to write popularization discourse as part of an interdisciplinary training program face, is that they need to learn to represent interdisciplinary methodology and research results. When working from an integrationist point of view, i.e., from the epistemological point of view that disciplinary insights should be integrated to form a more encompassing answer to the research question (see Repko & Szostak, 2021), interdisciplinary methodology produces multiple disciplinary answers as well as one interdisciplinary answer to the research question. In a popularization text, these multiple perspectives should all be presented in an easily accessible way, which requires a combination of popularization strategies (Sterk, 2023).

Set-up of the design

Four pedagogical frameworks together shaped the design and construction of the intervention. (i) *Constructivism* is a learner-centered theory in which learners construct meaning through interaction with the outside world (Piaget, 1950). The teacher is seen as a facilitator: “what the student does is actually more important in determining what is learned than what the teacher does” (Shuell, 1986, p. 429, see also King, 1993 for similar ideas about active learning). (ii) *Constructive alignment* is a form of outcomes-based education that is modeled on constructivist theory and that focuses on the coherence between the different stages of teaching; intended learning outcomes form the basis for learning activities and are tested in assessment tasks – these are all aligned amongst each other (Biggs & Tang, 2007). (iii) The *genre approach* to teaching writing consists of an introduction of the genre pattern, exercises to analyze this genre, exercises to practice language forms, and an assignment to write a short text in the genre (Dudley-Evans, 1997). It also includes a cycle of practice in writing, and feedback and reflection on that writing (Devitt, 2015). (iv) *Explicit teaching of genre* is defined by a discussion about the genre, an explanation of genre features, and of an expression of the underlying genre rules (Freedman, 1993). Practice that is rooted in reality, is key to genre learning (Purcell-Gates et al., 2007).

The intervention was developed in an iterative design cycle lasting four academic years. Eight consecutive designs were piloted, and a needs assessment was conducted in the final two iterations of the design cycle. The final design was constructed using four design principles (see Table 1) and contained learning outcomes in terms of knowledge, skills, and attitudes (see Table 2). The intervention consisted of five lesson components, the first and last of which took place outside of class: preparation (writing an individual popularized newspaper article), plenary instruction (e.g., theory about popularization discourse, genre features, popularization strategies (see Sterk & Van Goch, 2023)), exercises (e.g., reformulation and recontextualization of academic texts), analysis (students analyze their own newspaper article using the grading rubric), and writing (students collaboratively rewrite their newspaper article). The individual newspaper article assignment and the in-class assignments were linked to the final collaborative writing assignment, thus enabling constructive alignment. It received a summative assessment using a grading rubric for popularization discourse (see Appendix A) and made up 10% of students’ final grade.

Table 1

Design principles

1	Use explicit instruction to give insight into the genre of popularization discourse, the text form of the popularized newspaper article, the two main processes in popularization of reformulation (rephrasing in comprehensible language) and recontextualization (presenting information in an applied or everyday context), and popularization strategies.
2	Work with one example text to show the theory from design principle 1 in practice.
3	Have students reflect on their own writing and have them analyze their own texts.
4	Combine individual writing with collective writing.

Table 2
Learning outcomes

Theme	Learning outcome
Knowledge	Genre knowledge of popularization discourse
Skills	The ability to write a text congruent with the genre of popularization discourse The ability to recontextualize and reformulate academic insights from students' own research into popularization discourse suitable for a non-expert audience
Attitudes	Enthusiasm to communicate about students' own research to a non-expert audience Willingness to communicate about science outside of university courses

Procedure

The course was taught four times per year, and the study was conducted during all teaching blocks of the 2022-2023 academic year. The intervention was taught twice by the first and twice by the second author, who were also course coordinator in those blocks. The first author was also the interdisciplinary advisor of six student teams.

Research data were collected in accordance with guidelines of and after approval from the Faculty Ethics Assessment Committee Humanities (FEtC-H) at Utrecht University. An information letter was uploaded to the online course environment two weeks prior to the intervention. At the start of the intervention, information was given about the aim of the study, the data gathering procedure, and the treatment of data. All materials explicitly stated that participation was voluntary and that it would not impact students' grades or treatment in any way. Data was pseudo-anonymized after collection, after linking multiple data sources per participant.

Data gathering

Participants were asked to fill in a pre- and post-intervention questionnaire containing a combination of open-ended questions and Likert questions on a 1–5 scale (see Appendix B). Both questionnaires contained questions relating to declarative knowledge, procedural knowledge, and self-regulation. The construct *declarative knowledge* contained two items, relating to having a clear picture of what science communication is, and having sufficient knowledge of science communication to write a popularized text. The construct *procedural knowledge* consisted of four items, that asked for perception of skills in writing a popularized article and a newspaper article, being prepared for writing a popularized newspaper article, and confidence in effectively communicating about science to a non-academic audience. The construct *self-regulation* contained four items, pertaining to wanting to know more about science communication, choosing a course because writing a column or newspaper article was one of the assignments, believing science communication is an important part of scientific research, and feeling enthusiastic to communicate about own research to a broad audience. The post-intervention questionnaire contained an additional five open-ended questions pertaining to the intervention, the learning objectives, acquired knowledge and skills, and benefits of each in-class activity. The open-ended

questions were analyzed for remarks about declarative knowledge, procedural knowledge, and self-regulation.

Following the methodological set-up of the genre approach to teaching writing (Devitt, 2015; Dudley-Evans, 1997), after writing a short, popularized news article, students also reflected on that writing during class. “Experiencing their own performances is surely the most powerful way for students to learn to write better” (Devitt, 2015, p. 48) and thus students were asked to analyze their own writing using the course rubric. They then wrote a reflection using prompts about knowledge, skills, the writing process, the learning process, and the feedback process (see Appendix C). These self-reflections were analyzed for remarks about declarative knowledge, procedural knowledge, and self-regulation.

Data coding

Data were analyzed both quantitatively and qualitatively. In the quantitative analysis, only data of those participants that completed both questionnaires were used ($N = 57$). Table 3 shows the Cronbach’s alpha for each of the three constructs pre-intervention and post-intervention. Cronbach’s alpha ranged from 0.217 to 0.725, with most values in the 0.5–0.6 range, which is considered a poor internal validity. The pre-intervention data appeared to be normally distributed, as indicated by the similar mean and median, the skewness value of -0.143 ($z = -0.452$) and kurtosis value of 0.054 ($z = 0.09$), the Shapiro-Wilk normality test ($p = .268$) and visual assessments (histogram, Q-Q plots, box plot) showing approximate symmetry, despite one outlier. The post-intervention data, however, were not normally distributed. Mean and median were similar, skewness was -0.440 ($z = -1.392$), the Shapiro-Wilk normality test was not significant ($p = .158$) and visual assessments (histogram, Q-Q plots, boxplot) showed approximate symmetry. However, the kurtosis value was 1.435 with $z = 2.303$, neither of which falls within the acceptable range. Moreover, the histogram also showed positive kurtosis. Because the alphas for the constructs showed poor validity and the post-intervention data overall showed positive kurtosis, we decided to conduct the Wilcoxon signed-rank test, a non-parametric test, to compare individual questions pre- and post-intervention. To correct for multiple testing, the Bonferroni-correction was applied, in which the conventional alpha level of 0.05 is divided through the number of questions (19), to determine the new alpha level of 0.0026.

The open-ended questions in the pre-intervention and post-intervention questionnaire ($N = 57$) and the reflections ($N = 74$) were analyzed for the occurrence of any remarks about declarative knowledge, procedural knowledge, and self-regulation. Then, using thematic analysis, these remarks were clustered into themes. Thematic analysis is an iterative form of analysis where themes, or patterns of meaning, are systematically identified and analyzed from qualitative research data (Braun & Clarke, 2022). This part of the analysis was conducted by the first author, who coded the data in three iterative rounds, until consolidation was reached.

Table 3
Cronbach's alpha

Construct	Pre-intervention	Post-intervention
Declarative knowledge	0.217	0.418
Procedural knowledge	0.569	0.725
Self-regulation	0.530	0.632

Results

In this study, quantitative analysis of Likert scale questions from a pre-post intervention questionnaire and qualitative analysis of open-ended questions and a reflection were combined to determine undergraduate students' display of metacognitive awareness about popularization writing skills as an effect of explicit instruction in popularization discourse. The quantitative and qualitative results are clustered into the three forms of metacognition that were tested: declarative knowledge, procedural knowledge, and self-regulation.

Declarative knowledge

Table 4 shows the median pre-test and post-test scores for each question. Even though the data are ordinal, means are also reported for illustrative purposes. The statistical analysis showed that scores were significantly higher post-intervention compared to pre-intervention for both items pertaining to declarative knowledge: (i) "having a clear idea what popularization is" ($Mdn_1 = 4$, $Mdn_2 = 4$, $z = -4.286$, $p < .001$, with a moderate effect size: $r = -.401$) and (ii) "sufficient knowledge of popularization to write a popularization text" ($Mdn_1 = 2$, $Mdn_2 = 4$, $z = -5.036$, $p < .001$ with a moderate effect size, $r = -.472$).

In terms of the qualitative analysis, throughout the data many different linguistic strategies that can be used in science communication texts, i.e., textual components that were covered during the intervention, were mentioned by participants. Examples include making connections to daily life, contextualizing the results, or adding applied implications. The structure of the popular news article is referred to as the inverted pyramid, which is a structure very different from what students have learned during academic training: "Creating a structure where you start with the main point and then get more into depth, which is very different from an academic structure."

Participants learned about the terms recontextualization (placing the research findings in a new context) and reformulation (rephrasing for better comprehensibility): they know what the terms entail, why these processes are important, and how they can be applied. One participant indicated that "what I should consider more next time is that certain jargon needs to be explained. It might be wise to always assume that the reader is not familiar with any term and thus needs as much explanation as possible."

Participants declared the target audience to be important to consider in writing, and specified it as a broad audience, a non-expert audience, or a specific group connected to their thesis topic. Participants wrote about the genre demands of popularization mostly in an abstract form; they have acquired knowledge of the genre or the theory behind it. They mentioned the characteristics and demands of newspaper articles, the rules to writing one, and how they personally would write a newspaper article. Other remarks centred around the different forms and kinds of popularization, platforms, placement of information,

content, and writing style that are desired: “I now obtain more knowledge and understanding of what such a text should look like and what it should cover (and in which order).” Participants also learned about text quality, which they referred to in terms of text comprehensibility, text engagement, text clarity, and content of the text.

Table 4

Pre-test and post-test median and mean scores

Construct	Pre-intervention		Post-intervention	
	median	mean	median	mean
Declarative knowledge				
I currently have a clear idea of what popularization is	4	3.21	4	4.02
I have sufficient knowledge of popularization to write a popularization text myself	2	2.54	4	3.63
Procedural knowledge				
How do you rate your own skills compared to your fellow students when it comes to popularization texts	3	3.25	3	3.08
How do you rate your own skills compared to your fellow students when it comes to newspaper articles	3	2.96	3	2.97
I am well prepared for writing a popularization newspaper article	2	2.38	4	3.44
I feel confident when it comes to effectively communicating science to a non-expert audience	4	3.20	4	3.36
Self-regulation				
I would like to know more about popularization	4	3.32	4	3.31
If I would have the opportunity to write a column or newspaper article in a class, this is a reason for me to choose that class	2	2.15	2	2.31
I believe popularization is an important part of research	4	3.96	4	4.08
I am enthusiastic about communicating about my own research to a broad audience	4	3.57	4	3.77

Procedural knowledge

The statistical analysis showed that scores were significantly higher post-intervention compared to pre-intervention for one item regarding procedural knowledge, specifically: “being well prepared for writing a popularization newspaper article” ($Mdn_1 = 2$, $Mdn_2 = 4$, $z = -5.531$, $p < .001$ with a strong effect size, $r = -.518$). None of the other items showed a statistical significance and medians (and means) also remain roughly the same.

Participants often reflected on their procedural knowledge or showcased their procedural knowledge when talking about the progress in their writing skills, or lack thereof. According to participants, reformulation consists of using little jargon or deleting

it all together, explaining difficult terms, writing in a more journalistic style, writing as if explaining something to a friend, using as little numbers as possible, offering explanations that are less complex, and using simpler terms or accessible language: “I have tried not to use too much jargon and to explain the findings in a less complex way.” Participants have either already applied recontextualization, for example through a connection with daily life or society, stated it is a skill they have improved in class, or have not (yet) applied it. Some participants added they had a lack of knowledge about recontextualization pre-intervention: “I have learned how you can make a topic accessible for the audience, how you can make it more attractive, and how you can connect it to daily life.”

In terms of the target audience, participants’ aims were to make the text as attractive and exciting as possible, to connect to the audience’s experiences, and to get across their message: “Right now, I would target the text more to teens because this is the group we are talking about in our research.”

Writing style was deemed an important part of the writing process, with reflections on personal writing style, informal writing, a journalistic writing style, or more fun language. Participants explained this might be achieved by leaving out or explaining both disciplinary and interdisciplinary jargon, by explaining difficult concepts, or through the choice of words. Many participants stated their writing style was still too academic, and they needed to change this. Others reflected on the difficulties of not being able to state what they intended to without using jargon, or on the importance of doing justice to the content of the research even with a catchy writing style: “I judged myself to score average to high in explaining concepts and jargon, but after discussing this with my teammates, I came to the conclusion that a lot of words that I use in daily life are in fact not that standard to use.”

Many comments referred to procedural knowledge about strategy use. Participants stated they had not applied strategies yet, that they learned to apply strategies, or that they wanted to apply them in the future: “I was still missing a title; I hadn’t thought about it at all during writing. I did already brainstorm with my team during class about what the title might look like.”

To most, the writing process consisted of two elements: (i) application of the theoretical knowledge acquired in class, and (ii) focusing on the main themes of the thesis. Some read (parts of) their own thesis or thought about existing knowledge to establish a connection to society, while others just started writing, had a lack of time, or mentioned they had wanted to reread the interdisciplinary chapter of their thesis.

Participants thought practice was important to retain the newly acquired knowledge and they explicitly mentioned the importance of the group process, such as reading each other’s chapters or discussing their planning: “I will consult with my group about how we can communicate our academic research in the best and most interesting way. I think this is easier to do together because we all know our own disciplinary insights best.”

Participants looked up examples when writing their individual newspaper article; to learn more about this text type, specifically its structure and writing style, and to be able to emulate this type of text: “When I wrote my individual newspaper article, I first looked through newspapers, looking for different kinds of articles. I looked at language use, the

structure, and the typography of articles. I particularly paid attention to how complex and complicated theories were described by the author.”

Other important elements that were mentioned as part of procedural knowledge were reflection and creativity. Participants mentioned that they were able to critically read their own work, and to reflect upon their abilities and on the skills that needed improving. Participants remarked on creativity in both a positive and negative way; creativity was seen as part of the process of constructing popularization discourse, and it was employed for making a connection with society, but it was also seen as a barrier to the accurate representation of research findings in the media: “I sometimes feel that creativity has more importance than something that would logically fit (such as the topic of the newspaper article), and I think that this could devalue the significance of the research.”

Self-regulation

None of the items in the quantitative analysis related to self-regulation showed a statistically significant difference, with medians (and means) staying approximately the same.

The qualitative analysis showed that after taking part in the intervention, participants better understood the assignment and assessment criteria. They also reflected upon the expectations that were placed upon them and on the feasibility of those expectations, as well as on their own expectations. They stated they saw the use of popularization and had an increased interest in the topic: “I did not use a special approach when I wrote the newspaper article, because I had no knowledge yet of what exactly is needed in this type of communication. I just did what I thought fit the short description of the assignment in the syllabus.”

Many other remarks were made about improvement; some just stated that improvement in their writing was needed, while others supplied concrete examples of areas of improvement, such as reformulation of academic language, structure, and planning. Some participants even stated that everything needed improving: “In no way is my text a newspaper article LOL”.

Critical remarks about the intervention were also present. Some stated they learned little, the intervention was boring, or it was not useful to them: “I would rather just fully focus on my own thesis. That is more fun and more useful.”

Participants are used to academic writing: their newspaper articles were still written in the academic register, and they had difficulty with letting go of the academic writing style. The genre switch from academic to popularized discourse thus was difficult to achieve, and participants remarked that popularization writing was not easier than academic writing. It truly is a different way of writing a text: “The class has made me come to the realization that I still very much focus on academic language use, and that I really must let that go. I still have great strides to make.”

According to the participants, a lack of practice of writing during the intervention hampered an improvement in their skills. While they have acquired theoretical knowledge and insight into popularization strategies, knowledge alone is not enough. What is more, the time span of one intervention was seen as too short to acquire new skills or to see an improvement in them. More writing and receiving feedback will have a greater impact on writing skills than learning about theory: “It is difficult to say within the time span of three

hours that I have improved in writing a popularized newspaper article, but I do believe that thanks to this class I have obtained the right tools to get to work and write better newspaper articles in the future.”

Discussion

Empirical findings versus the literature

The quantitative analysis of our study has shown that taking part in explicit training in popularization discourse leads to an increase in declarative knowledge and some increase in procedural knowledge, while in the qualitative analysis participants showed they attained declarative knowledge, procedural knowledge, and forms of self-regulation. Participants’ reflections furthermore showed that training is indeed necessary to foster popularization writing skills (“I had no knowledge yet of what exactly is needed in this type of communication”), that participants had difficulties with the genre switch between academic and popularized discourse (“I still very much focus on academic language use, and that I really must let that go”), and that some also struggle with disciplinary versus interdisciplinary jargon (“I came to the conclusion that a lot of words that I use in daily life are in fact not that standard to use”). Thus, while the results from the two analyses partially overlap, they are also complementary. While the quantitative analysis shows an increase in confidence in some areas, the quantitative analysis highlights additional lessons learned, and areas for improvement.

As metacognition in relation to popularization is an unexplored topic in the academic literature, a direct comparison between our findings and previous findings cannot be drawn. More generally, though, the metacognitive awareness presented by the participants in this study shows some links to positive effects of training that were described in multiple sources from the literature. They include an increase in the sense of being informed (Crone et al., [2011](#)), feeling prepared for popularization writing (Heath et al., [2014](#)), coming to the realization that writing to nonprofessional audiences is difficult (Moni et al., [2007](#)), and feeling that practice improves skills (Brownell et al., [2013a](#)). Just as in the literature, there was a predominantly positive judgment of the training (see Latimore et al., [2014](#); Mercer-Mapstone & Kuchel, [2016](#)), but critical notes are also present (see Moni et al., [2007](#)). On the other hand, multiple sources showed an effect of training on self-perception of writing skills (Brownell et al., [2013b](#); Crone et al., [2011](#); Heath et al., [2014](#); Latimore et al., [2014](#); Mercer-Mapstone & Kuchel, [2016](#)), on confidence (Brownell et al., [2013b](#); Mercer-Mapstone & Kuchel, [2016](#); O’Keeffe & Bain, [2018](#)), or on attitude (Mercer-Mapstone & Kuchel, 2016; Moni et al., [2007](#)), while this was not reflected unambiguously in this study.

Sterk ([2023](#)) noted that popularization texts about interdisciplinary research need to include both the multiple disciplinary insights and the interdisciplinary insight. Participants often referred explicitly to the disciplinary or the interdisciplinary insights, most likely prompted by the assessment criteria in the rubric. Yet they never commented on how they presented the two in relation to each other, or which (different) text strategies they used in doing so. This could be explained because cognitively, connecting disciplinary

to interdisciplinary insights is one of the most difficult steps in interdisciplinary research, one that students struggle with often.

Limitations

This study led to insightful knowledge about students' metacognitive awareness. However, we also discuss this study's limitations.

We had intended to group the questions for the quantitative analysis into constructs, one for declarative knowledge, procedural knowledge, and self-regulation, so that we could treat the results as interval instead of ordinal data and could then perform a parametric test (paired samples T-test). Unfortunately, the Cronbach alpha was too low for each construct. We thus used the Wilcoxon signed-rank test, but as this is a non-parametric test that operates with ordinal data, it is less powerful.

Four pedagogical frameworks together shaped the design and the construction of the intervention; constructivism (Piaget, 1950) and constructive alignment (Biggs & Tang, 2007) which focus on the learning environment, and a genre approach to writing (Devitt, 2015; Dudley-Evans, 1997) and explicit teaching of genre (Freedman, 1993; Purcell-Gates et al., 2007) that focus on how writing processes and genre demands are being taught. There are some critical remarks to be made regarding these choices. The use of constructive alignment enabled coherence between intended learning outcomes, learning activities, and assessment tasks – yet it is exactly this alignment that also rigidifies the learning process. A learning experience that the student goes through is not always the same as what an educational designer had intended, and assessment tasks focus more on outcome measures than do on skills or learning strategies that students acquire – especially the “softer” skills such as building curiosity. The outcome measures in this intervention focussed on knowledge, skills, and attitudes, while the capabilities that students need to acquire to truly be well-trained popularization writers are more wide-ranging and often also take more time to be nurtured.

Constructive alignment furthermore hinges on grading of the intended learning outcomes; this might not always be the most beneficial way to build a favourable attitude to the learning materials, as fulfilling the assessment might turn into a tick-box students just ‘need to get done’ to fulfil the requirements of the course. This could get in the way of fostering true passion or interest in the topic or skills. Thus, instead of designing for learning outcomes, we could have adopted a more process-oriented approach. In that way, we would have focussed more on *how* students acquire skills – and through it, metacognitive awareness – and in which different ways they might do so. Examples are paying more attention to experimenting with writing, dealing with uncertainty in writing, or letting students have a hand in co-constructing the educational materials. Implementing a reflective exercise was a first step in focussing on the learning process, but constructive alignment in a sense dissuaded us from engaging with the lived aspects of the learning process, which might in turn have also impacted students' metacognitive awareness.

Another point of discussion is the way in which the pedagogical frameworks of a genre approach to writing and explicit teaching of genre can be executed well in one four-hour session. Here, we would like to echo the sentiment of the participants, and state that

more time and more practice in popularization training are needed to truly implement these two approaches, and to enable students to optimally learn to write popularization discourse.

Conclusion

The aim of this study was to determine how explicit instruction in popularization discourse influences metacognitive awareness about popularization writing skills in undergraduate interdisciplinary students. Students of an interdisciplinary program at the end of their undergraduate training took part in one four-hour teaching intervention about popularization writing skills. The data from their reflections and questionnaires were analyzed both quantitatively and qualitatively to determine their metacognitive awareness. The quantitative analysis shows an increase in declarative knowledge in terms of having a clear idea of what popularization is and having sufficient knowledge to write a popularization text, and an increase in procedural knowledge in terms of being prepared to write a popularization newspaper article. The qualitative analysis shows that students have attained declarative knowledge in the form of popularization as a genre through knowledge about text strategies, recontextualization, reformulation, and the target audience; procedural knowledge into how to produce popularization discourse through insight into through reformulation, recontextualization, appropriate writing style, and the use of practice, examples, and creativity; and self-regulation by managing their expectations of popularization writing and the assignment, but also by gaining the insight that the switch from academic writing to popularization discourse can be difficult, and the importance of getting enough practice in writing.

Implications

This study has shown that even an intervention that is as small as one four-hour class has a positive effect on students' metacognitive awareness, which would imply that offering a single lesson in popularization could already be beneficial for university students – especially when it comes to declarative knowledge in the form of genre knowledge and expectations. This study thus also shows that for true development in metacognition to come into fruition, students need to be offered more time and structural options to practice their popularization writing. Educational materials could include the use of examples in class and as a guideline during writing, reflection on students' own written products, and deliberation with other students about their texts or writing approach. For interdisciplinary students, it could be beneficial to discuss how both disciplinary and interdisciplinary insights can be presented in popularization texts.

Future research

In this study, the post-intervention measurements were all taken relatively quickly after the teaching intervention; future research could add additional measurements at later points in time, to also test for the long-term impact of such an intervention.

Future research could also test the effectiveness of the intervention through measuring improvement in popularization writing skills. This study focused solely on metacognitive awareness as a result of the intervention but could have benefited from

additional data on student performance. Future work could for example score individual student writing pre-intervention to collective writing scores post-intervention.

Alternatively, research could focus on the way in which students produce texts when they are writing collaboratively as a team, and on how they use the individual texts as sources in their writing. Lastly, future research could focus more on the *process* of learning more than content knowledge or specific writing skills, and through it, see the effects on students' metacognitive awareness.

Ethics statement

Research data were collected in accordance with guidelines of and after approval from the Faculty Ethics Assessment Committee Humanities (FEtC-H) at Utrecht University, approval number 22-101-03.

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Conflict of interest

The author(s) declare none.

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Appendix A. Rubric

Newspaper article title:

Student names:

Target audience and platform:

Knock-out criteria	Pass		Fail	
The assignment falls within the word range (600-800 words)	Between 600 and 800 words		Less than 600 or more than 800 words	
	8-10	6-8	5-6	1-5
Results (20%)	The content is easy to understand for a non-specialized target audience	The content is reasonably understandable for a non-specialized target audience	The content is somewhat understandable for a non-specialized target audience	The content is not understandable for a non-specialized target audience
Disciplinary insights (20%)	Disciplinary insights are fluently incorporated in the text	Disciplinary insights are explained	Disciplinary insights are named	Disciplinary insights are not presented in the text
	Interdisciplinary insights are fluently incorporated in the text	Interdisciplinary insights are explained	Interdisciplinary insights are named	Interdisciplinary insights are not presented in the text
Context (20%)	The text is completely adapted to the target audience	The text is reasonably adapted to the target audience	The text is barely adapted to the target audience	There is no consideration for the target audience
	Connections to daily life or society support the story	Connections to daily life or society are presented	Connections to daily life or society are hardly visible/not elaborate	No connections are made to daily life or society
Formulation (20%)	(Inter)disciplinary jargon is used where necessary, and it is always explained	(Inter)disciplinary jargon is used, which is often explained	(Inter)disciplinary jargon is used which is hardly ever explained	A lot of (inter)disciplinary jargon is used which is never explained
	The writing style is journalistic	The writing style is predominantly journalistic	The writing style is predominantly academic	The writing style is academic

	The writing style matches the chosen platform very well	The writing style matches the chosen platform	The writing style somewhat matches the chosen platform	The writing style does not match the chosen platform
	The text contains little to no errors and is understandable	The text contains some errors and is reasonably understandable	The text contains a lot of errors and is difficult to understand	The text contains too many errors and is unreadable
Structure (20%)	The structure of the newspaper article supports the story	The text has the structure of a newspaper article	There is a structure, but not that of a newspaper article	There is no recognizable structure
	The core message is clear and sticks	The core message is recognizable but does not stick	The core message is not recognizable as such	There is no core message

Appendix B. Questionnaire

Pre-class questionnaire

This questionnaire consists of five questions: three closed questions about writing skills and skills in popularization, and two open questions about courses you have taken before and about your expectations for this class.

1. How do you rate your own skills compared to your fellow students when it comes to the following forms of writing (1 = majorly below average, 2 = below average, 3 = average, 4 = above average, 5 = majorly above average, N/A = I have never written such a type of text before):
 - (a) Academic texts
 - (b) Popularization texts (= writing for a non-expert audience)
 - (c) Newspaper articles
2. Determine to what extent you agree with the statements below (1 = strongly disagree, 2 = disagree, 3 = no opinion, 4 = agree, 5 = completely agree)
 - (a) I currently have a clear idea of what popularization is
 - (b) I have sufficient knowledge of popularization to write a popularization text myself
 - (c) I am well prepared for writing a popularization newspaper article
 - (d) I feel confident when it comes to effectively communicating science to a non-expert audience
 - (e) I would like to know more about popularization
 - (f) If I would have the opportunity to write a column or newspaper article in a class, this is a reason for me to choose that class
 - (g) I believe popularization is an important part of research
 - (h) I am enthusiastic about communicating about my own research to a broad audience
3. How do you assess your own skills compared to your fellow students when it comes to the following elements of popularization? (1 = majorly below average, 2 = below average, 3 = average, 4 = above average, 5 = majorly above average)
 - (a) Identifying and analyzing a target audience
 - (b) Using appropriate language to communicate about science
 - (c) Thinking about existing prior knowledge of the target audience
 - (d) Separating essential from non-essential information
 - (e) Thinking about the social, political, and cultural context of an academic issue
 - (f) Identifying the purpose and outcome of communication
 - (g) Using style elements such as analogy and metaphor
 - (h) Visualizing data effectively
4. Have you previously taken part in a course on popularization, or a course that included popularization? If so, which course(s)?
5. Today's class focuses on popularization, in preparation for the science communication assignment, which consists of writing a newspaper article about your thesis. What would you like to learn in this class?

Post-class questionnaire

This questionnaire consists of eight questions: four closed questions about writing skills, popularization skills, and the learning objectives of today's class, and four open questions about your knowledge, skills, attitude, and the learning process.

1. How do you rate your own skills compared to your fellow students when it comes to the following forms of writing (1 = majorly below average, 2 = below average, 3 = average, 4 = above average, 5 = majorly above average, N/A = I have never written such a type of text before):
 - (a) Academic texts
 - (b) Popularization texts (= writing for a non-expert audience)
 - (c) Newspaper articles
2. Determine to what extent you agree with the statements below (1 = strongly disagree, 2 = disagree, 3 = no opinion, 4 = agree, 5 = completely agree)
 - (a) I currently have a clear idea of what popularization is
 - (b) I have sufficient knowledge of popularization to write a popularization text myself
 - (c) I am well prepared for writing a popularization newspaper article
 - (d) I feel confident when it comes to effectively communicating science to a non-expert audience
 - (e) I would like to know more about popularization
 - (f) If I would have the opportunity to write a column or newspaper article in a class, this is a reason for me to choose that class
 - (g) I believe popularization is an important part of research
 - (h) I am enthusiastic about communicating about my own research to a broad audience
3. How do you assess your own skills compared to your fellow students when it comes to the following elements of popularization? (1 = majorly below average, 2 = below average, 3 = average, 4 = above average, 5 = majorly above average)
 - (a) Identifying and analyzing a target audience
 - (b) Using appropriate language to communicate about science
 - (c) Thinking about existing prior knowledge of the target group
 - (d) Separating essential and non-essential information
 - (e) Thinking about the social, political, and cultural context of an academic issue
 - (f) Identifying the purpose and outcome of communication
 - (g) Using style elements such as analogy and metaphor
 - (h) Visualizing data effectively
4. The lesson is designed based on the following learning objectives:
 - (a) Developing genre knowledge of popularization discourse
 - (b) Writing a text that is congruent with the genre of popularization discourse
 - (c) Being able to place academic insights from your own research in a new context in a popularized text that is suitable for a non-expert audience
 - (d) Rewriting a self-written academic text (= thesis) into a popularized text that is suitable for a non-expert audience

5. Determine to what extent you agree with the statements below (1 = strongly disagree, 2 = disagree, 3 = no opinion, 4 = agree, 5 = completely agree)
 - (a) I worked on this learning objective during the class
 - (b) I have improved the skills that are useful for this learning objective
 - (c) I enjoyed working on this learning objective
6. What kind of content knowledge have you gained from attending today's class?
7. Which skills did you acquire or improve by attending today's class?
8. Have you become better at writing a popularized newspaper article? What has contributed to or hindered this?
9. The class contained three major components. What have you learned from each activity?
 - (a) Plenary explanation about writing a newspaper article and the processes of reformulation and recontextualization
 - (b) Hands-on assignments to work on reformulation and recontextualization
 - (c) Analysis of and reflecting on your own newspaper article

Appendix C. Logbook writing

1. Make an assessment of your newspaper article by filling in the rubric
2. Write a reflection about:
 - What was your approach to writing this individual newspaper article?
 - On which assessment criteria do you already score well, and which criteria could you score better on?
 - Which suggestions for improvement would you give to yourself?
 - Which parts from your newspaper article are suitable to include in your collective newspaper article, and why?
 - Think back to the recontextualization, reformulation, and text strategies that we have been talking about in this lecture. Have you applied any recontextualization, reformulation, or specific text strategies while writing this newspaper article? If so, in which part(s) of the text and how?
 - What have you learned about your own writing/writing skills as a result of the lecture and the assessment of your own individual newspaper article?
 - What will you approach differently when writing the joint newspaper article?