



Teaching Science Communication with Comics for Postgraduate Students

Olivier Robin^{1,2*}, Benoît Leblanc^{2,3} and Nancy Dumais^{2,3}

¹Département de génie mécanique, Faculté de génie, Centre de Recherche Acoustique-Signal-Humain, Université de Sherbrooke, Sherbrooke, QC, Canada, ²Centre compétences recherche+, Université de Sherbrooke, Sherbrooke, QC, Canada, ³Département de biologie, Faculté des sciences, Université de Sherbrooke, Sherbrooke, QC, Canada

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*Correspondence:

Olivier Robin
olivier.robin@usherbrooke.ca

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Data visualization and visual storytelling are increasingly common terms when institutions and scientists want to introduce people to their research and science through stories. Yet institutions mostly teach and train their scientists in the language of science and scientific journals, whereas research dissemination calls for other forms of communication. A new university course introducing such a new form of communication is proposed to postgraduate students at Université de Sherbrooke since January 2020. Its main objective is to help students develop their general interest and skills into science communication using comics as a working medium. While following a simple path, this course has generally led to results beyond initial expectations and large engagement from students. This study describes the general context and structure of the course, analyzes feedback from participants, presents some results, and summarizes lessons learned to help the diffusion of such a cross-disciplinary course.

Keywords: science communication, comics, postgraduate course, research dissemination, survey

1 INTRODUCTION

The great majority of scientific work is generated and communicated in the form of academic studies. Their yearly number has grown by a third since the beginning of the 21st century (Wilsdon et al., 2011) and reached an estimated value of 1,500,000 studies in 2015 (Unesco, 2015). This data deluge combined with the use of an arcane scientific language limits the impact and awareness of scientific discoveries to a narrow and specialized audience. It also raises questions about how a scientific study is currently presented and/or written and how scientific information can be communicated to diverse users in diverse ways (Sopinka et al., 2020). Increasingly, authors and publishers look to including non-traditional or additional research artifacts in publications so as to enhance interactions. The *Acta Acustica* journal recently launched “Audio Articles,” a type of scientific article with embedded audio files in the PDF and HTML versions of the article. Reactive and interactive diagrams are also proposed in digital publishing, and graphical abstracts are becoming ubiquitous (Nature Chemistry, 2011).

In this context of a fast growing rate of science contents, the importance of science communication or research dissemination has increased for scientists and institutions to make research accessible to a wider audience but also to justify and stimulate funding (Ross-Hellauer et al., 2020). As the progress in different fields of science increasingly impact our understanding of the world and the way it is governed, the scientific community faces the challenge of communicating in efficient, clear, and engaging ways findings that are ever more complex. Considering how many variables may have to be considered to give an accurate view of any given field, this is however not

always readily feasible. To wit, a 2016 study evaluating successive summaries by the Intergovernmental Panel on Climate Change Summaries for Policy Makers determined that this extremely important document remained of low readability despite considerable efforts (Barkemeyer et al., 2016). It is in this context of having to explain in more engaging ways concepts that are ever less easy to summarize that this project was instigated.

Ideal scientists should thus surely own a scientific language to interact with peers, but they should also develop abilities to communicate their science using compelling approaches such as different ways of telling stories. Indeed, storytelling/narratives are keywords that are often seen to describe a new practice for scientists to share their messages and findings in an engaging way (Flemming et al., 2018; Green et al., 2018; Hoffmann, 2020). Combining storytelling and science is sometimes discussed (Katz, 2013; Nature Methods, 2013) but is generally strongly advised to strengthen the interface between science and practice or between science and human beings (Krzywinski and Cairo, 2013; Arevalo et al., 2020; Jones and Crow, 2020; Muindi et al., 2020). To coin a phrase, data makes a story more credible and a story makes data less boring. Scientists can be portrayed as individuals and their motivation for research can be made relatable, and using a narrative style in an article can even positively impact its citation rate (Hillier et al., 2016). As a consequence, data-driven storytelling (Riche et al., 2018) is becoming a field in its own right and showcases interactive visualizations for science communication and education. Arts, educational games¹, entertainment, imagination, and creativity are finally being included into teaching and learning approaches (Fahnert, 2019; Robin and Jaouen, 2019).

While having been the object of various criticisms (Wertham, 1954) and considered to be a subliterate for a long time, comics are now a legitimate art form, *the ninth art*, and an academic discipline² along with its specialized journals (few examples are: SANE journal: Sequential Art Narrative in Education; Journal of Graphic Novels and Comics; and The Comics Grid: Journal of Comics Scholarship). The fact that comics can be recognized as a legitimate form of academic publication has been demonstrated by several authors (Tisseron, 1975, 2009; Hureau, 2019; Sousanis, 2015). Comics are also considered as a full-fledged tool for disseminating and explaining science. Since the 1940s (Sones, 1944), comics have been generally seen as a valuable educational resource (Morel et al., 2019; Scavone et al., 2019; Kirtley et al., 2020) and science comics are now highly common (Schultz et al., 2009; Doxiadis et al., 2009; Hosler, 2013; Harder, 2015). Initiatives linking comics and science dissemination are mushrooming, including specialized websites³, cooperations⁴, and specialized meetings (Telling science–drawing science⁵). A

comic book presenting the study of ten doctoral students and drawn by professional cartoonists has been published for the five last editions of the annual French national science fair, reaching 80,000 copies in 2019. The European research council launched the “ERCcOMICS” initiative⁶ in 2014 that aims to circulate web comics promoting and explaining the achievements of 18 funded European research projects. More and more researchers advocate a larger use of comics in science (Farinella, 2018a,b,c; Scavone et al., 2019). One current trend is designated by the compound and new term “data comics” (Zhao et al., 2015; Bach et al., 2017; Wang et al., 2019a,b), which is praised for teaching data visualization and storytelling. Data comics can even help to humanize data for complex topics, typically related to health (McNicol, 2016; Alamalhodaie et al., 2020). Examples of graphical abstracts taking a comic-like form are becoming common (Caudron and Barral, 2013; Poisson et al., 2020). Creating comics is generally found to have a positive effect on students (Scavone et al., 2019) and comics–science workshops are more and more being evaluated for younger people (Tatalovic, 2009; Hosler and Boomer, 2011; Spiegel et al., 2013; de Hosson et al., 2018) or undergraduate students with a background in arts (Wang et al., 2019a). While guidelines or instructions for using this medium are now provided in the form of academic works (Friesen et al., 2018; McDermott et al., 2018), concrete initiatives to train graduate and postgraduate students to the use of comics in their research project remain scarce. All these initiatives are mostly held by external facilitators (de Hosson et al., 2018) and rarely by academic institutions.

While these observations show that comics are increasingly accepted as a valid, versatile, and engaging teaching resource, a significant hurdle in their widespread adoption is that relatively few people consider themselves to be sufficiently skilled artistically to consider producing their own; as with any field requiring a certain technical expertise, the first step might appear a little daunting. Here, we hypothesize that independent of a communicator’s artistic skills or prior familiarity with comics, it is possible to devise a very focused course introducing science communicators to the basics of comics’ grammar and to provide the technical skills required for even a neophyte to create comics of high quality.

Such a course has been devised as part of a global program to develop postgraduate students’ transdisciplinary skills and has been offered since January 2020 at Université de Sherbrooke (EFD919-Communication scientifique par la bande dessinée/Science communication with comics, two academic credits). The course has currently been given on four distinct semesters. Since it is offered to any faculty of school of the university, participants profiles generally include a broad range of specialties (examples are engineering, natural sciences, health studies, biology, quantum mechanics, education, management, and law). While the course only includes 12 h of traditional teaching, the involvement of students and the results obtained generally exceed all expectations. Self-assessment of participants furthermore

¹<https://explorabl.es/>

²<https://uqo.ca/emi>, <https://www.dundee.ac.uk/subjects/comics>, <https://humanitiesliberalstudies.sfsu.edu/minor-comics-studies>

³www.cartoonscience.org, <https://www.datacomics.net/>, <https://www.graphicmedicine.org/>

⁴<https://www.stimuli-asso.com/>

⁵<https://sarabandes2016.sciencesconf.org/>, <https://tsds2019.sciencesconf.org/>

⁶<https://www.erccomics.com/>

indicate a strong confirmation of our hypothesis, as a vast majority of responders reported an important or very important progress in their science communication skills and their confidence in using comics for science communication.

So as to share this experience, this communication describes the global methodology used for the course including setup, organization, and assignments. The benefits for participants in terms of science communication are analyzed using surveys. Lessons learned and future directions of this course are finally discussed, together with the possible uses for student's works.

2 METHODS

2.1 Course Organization and Attendance

The EFD919 course was given during Winter 2020 (W20), Summer 2020 (S20), Winter 2021 (W21), and Summer 2021 (S21) semesters. The three objectives of the course are 1) to train researchers to science communication, 2) to help them develop transdisciplinary skills, and 3) to generate concrete contents for science communication. Over the four teaching sessions, 42 students followed and passed the course. Among them, 45% were women ($N = 19$), 55% were men ($N = 23$), and 74% were international students ($N = 31$).

The two teachers have proven skills in comics and science communication and have designed the course materials and organization. It is composed of four workshops of 3 h long each, and each spaced by approximately 3 wk in order to allow sufficient time to elaborate and complete each intermediary work. The course was given in a classroom-based approach in Winter 2020 and Summer 2021 sessions and using an online teaching platform in Summer 2020 and Winter 2021 sessions given the COVID-19 pandemic. Even if this lowered the interactions level, the teachers did not notice a firm difference between classroom and online results.

For all the teaching sessions, the breakdown of the course was as follow:

- The first workshop integrates theoretical and general aspects concerning science communication, tools commonly used to disseminate content, and concrete examples of comics use within this area. The students are asked to write a summarized while popularized text concerning their research as a preliminary work (to be submitted prior the workshop, 300–400 words long). Each student introduces her/himself and has to summarize its research using popularized terms.
- The second workshop introduces the use of tools (free and open-source digital drawing software such as Krita, Medibang, or Inkscape). Comics grammar is also introduced (balloons, strips, and sketches), and examples of script breakdowns are discussed. Students briefly present their first breakdown of their scenario (popularized text transformed into a story) and then work in small groups (two to four people) to discuss/improve/elaborate their

story. Teachers provide occasional interaction with groups for advices and suggestions.

- The third workshop first covers additional technical points like lettering, fonts, and balloons. Each participant presents his/her first drawn work and explains narrative choices to the group. This allows attendees to receive and provide comments and suggestions.
- The fourth workshop is fully devoted to the presentation of final works. Each comic is read publicly, and again all attendees are asked to receive and provide immediate reactions and comments.

Between workshops, the teachers provide individual feedback to all participants (concerning submitted intermediary works but also to answer to more specific questions, technical or general). To ensure inclusiveness, the workshops are systematically composed of several teaching and learning methods as well as varied educational content (lectures, multiple techniques, multimedia tools, and online videos). As pointed out in the course's breakdown, each work is evaluated and discussed by the teachers but also by the other participants during the workshops. Joint work and group feedback provide source FOR emulation and sharing of ideas and help verify understanding of key messages. Completion of the course requires the submission of a final drawn work to be used in any context (article, scientific presentation, interactions with the general public, and individual development, *see* two examples in the Results section). The advised type of work is two-page comics to have sufficient space to describe a subject but also to limit the amount of work to be done. Two-page comics represent approximately two-thirds of final works. Depending on the chosen support and subject, other typical outputs are posters, one-page comics, or more-than-two-page comics (some students even expanded their work up to eight to nine pages).

2.2 Surveys

Data were collected from three online surveys administered through the Moodle learning management system. Attendees received an initial notification about the surveys from the course teachers, and then two recruitment emails, each 5 days apart approximately. It is precised that a generally larger number of answers was obtained for the pre-course survey, since some students that initially registered for the course did not finally attend (especially for W21 session). All answers were nevertheless kept. The pre-course survey was designed to take respondents 5 min to complete and assessed each participant expectations and background for the course using close-ended questions. This survey was only administered after the course has been taught for the first time (i.e. after W20 session), and thus three teaching sessions are considered. The two post-course surveys were designed to take respondents 10 min to complete. The first post-course survey assessed the course impacts in terms of earned experience and knowledge, using close-ended questions. The second post-course survey aimed at collecting information concerning the use of comics and its components within the frame of science communication, and from the students

Workshop #1

EFD919 – Communication scientifique par la bande dessinée Silouane de Reboul – 26/01/2020

La simulation aéroacoustique

L'acoustique

L'acoustique est l'étude des ondes sonores, des vibrations de l'air qui se propagent jusqu'à nos oreilles. Ces ondes peuvent être générées par de nombreux phénomènes différents : des choses qui vibrent (les cordes et la table d'harmonie d'une guitare ou la membrane d'un haut-parleur), des objets qui frottent les uns contre les autres (une porte qui grince), des chocs (un marteau-piqueur), etc.

L'aéroacoustique

L'aéroacoustique est l'étude du bruit produit par une source particulière : la turbulence dans un écoulement. Par exemple, quand le vent croise une éolienne sur son chemin, cet obstacle le perturbe et de nombreux tourbillons apparaissent autour des pales. Ces petits mouvements de l'air sont responsables du bruit produit.

On peut citer de très nombreux autres bruits d'origine aérodynamiques : celui de l'air mis en mouvement par les voitures sur l'autoroute, celui des réacteurs des avions, des pales des hélicoptères, des drones, mais aussi les battements d'ailes des oiseaux, le sifflement du vent dans les arbres, etc.

La simulation numérique

Pour connaître un bruit, on dispose principalement de deux moyens :

- 1) On peut utiliser un micro pour le mesurer.
- 2) On peut chercher à le prédire, le calculer. Pour cela, les scientifiques partent les lois de la physique, les appliquent à leur problème et cherchent à résoudre ces équations. Comme elles sont difficiles à résoudre, la simulation numérique est l'utilisation d'algorithmes pour trouver des solutions approchées à ces équations.

A quoi ça sert ?

Imaginez un fabricant de voiture, qui souhaite que le bruit à l'intérieur de ses véhicules soit suffisamment bas pour que les utilisateurs puissent discuter entre eux sans crier, même à 150 km/h sur l'autoroute. Ce constructeur a donc besoin de connaître le bruit de sa voiture. On a vu précédemment qu'il y avait deux méthodes pour cela :

- 1) Il construit sa voiture, la fait rouler, et mesure le bruit à l'oreille du conducteur ou des passagers avec un micro. Si le bruit lui convient, il peut vendre sa voiture. Si le bruit est insupportable, on met la voiture à la casse, les plans à la poubelle, les ingénieurs au chômage, et on recommence.
- 2) Il utilise la simulation numérique pour prédire le bruit de sa future voiture avant même qu'elle ne soit construite. Si le bruit ne convient pas, il suffit de reprendre les plans. Ceci lui permet d'économiser du temps, de l'argent, et des ressources naturelles.

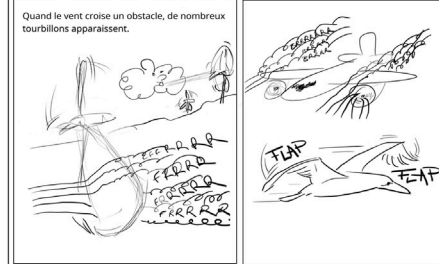
Workshop #2

$(\sum_{i=1}^n x_i^2 - \frac{1}{n} (\sum_{i=1}^n x_i)^2) p = \text{VROOAAA}$
OU LA FOLLE HISTOIRE DE L'AÉROACOUSTIQUE

L'acoustique est l'étude du son, des vibrations de l'air qui se propagent jusqu'à nos oreilles. Elles peuvent être produites par de nombreux phénomènes différents :



L'aéroacoustique est la branche de l'acoustique qui s'intéresse à une source particulière : les tourbillons dans un écoulement d'air.



Workshop #3

$(\sum_{i=1}^n x_i^2 - \frac{1}{n} (\sum_{i=1}^n x_i)^2) p = \text{VROOAAA}$
OU LA FOLLE HISTOIRE DE LA SIMULATION AÉROACOUSTIQUE

L'ACOUSTIQUE EST L'ÉTUDE DU SON, DES VIBRATIONS DE L'AIR QUI SE PROPAGENT JUSQU'À NOS OREILLES. ELLES PEUVENT ÊTRE PRODUIES PAR DE NOMBREUX PHÉNOMÈNES DIFFÉRENTS :

DES OBJETS QUI VIBRENT... ... QUI FROTTENT... ... QUI COGNENT...

L'AÉROACOUSTIQUE EST LA BRANCHE DE L'ACOUSTIQUE QUI S'INTÉRESSE À UNE SOURCE DE BRUIT PARTICULIÈRE : LES TOURBILLONS DANS UN ÉCOULEMENT D'AIR.

POUR CONNAÎTRE UN BRUIT, ON DISPOSE PRINCIPALEMENT DE DEUX MOYENS :

MÉTHODE 1 : LE MESURER AVEC DES MICROS

MÉTHODE 2 : LE PRÉDIRE AVEC LA SIMULATION NUMÉRIQUE

Workshop #4

$(\sum_{i=1}^n x_i^2 - \frac{1}{n} (\sum_{i=1}^n x_i)^2) p = \text{VROOAAA}$
OU LA FOLLE HISTOIRE DE LA SIMULATION AÉROACOUSTIQUE

L'ACOUSTIQUE EST L'ÉTUDE DU SON, DES VIBRATIONS DE L'AIR QUI SE PROPAGENT JUSQU'À NOS OREILLES. ELLES PEUVENT ÊTRE PRODUIES PAR DE NOMBREUX PHÉNOMÈNES DIFFÉRENTS :

DES OBJETS QUI VIBRENT... ... QUI FROTTENT... ... QUI COGNENT...

L'AÉROACOUSTIQUE EST LA BRANCHE DE L'ACOUSTIQUE QUI S'INTÉRESSE À UNE SOURCE DE BRUIT PARTICULIÈRE : LES TOURBILLONS DANS UN ÉCOULEMENT D'AIR.

POUR CONNAÎTRE UN BRUIT, ON DISPOSE PRINCIPALEMENT DE DEUX MOYENS :

MÉTHODE 1 : LE MESURER AVEC DES MICROS

MÉTHODE 2 : LE PRÉDIRE AVEC LA SIMULATION NUMÉRIQUE

FIGURE 1 | First example of the course outcomes: Workshop #1: initial popularized text; Workshop #2: first graphical breakdown; Workshop #3: second graphical breakdown; Workshop #4: final colored work (Silouane de Reboul, La simulation aéroacoustique - Aeroacoustics simulation).

standpoint (how they used comics' features and elements in their work?). The questions and possible answers for each survey and corresponding results are reported in the

following section. The pretest survey return rate was 95% while the two post test surveys return rate was approximately 80% (S21 session had the lowest response rate).

TABLE 1 | Results of the pre-course survey over three teaching sessions.

Question 1					
How would you qualify your general knowledge of science communication?					
Possible answers	Very low	Low	Median	High	Very High
S20 (N = 11)	0	1	5	4	1
W21 (N = 17)	1	4	8	4	0
S21 (N = 9)	0	1	7	1	0
Overall (in %, N = 37)	3	16	54	14	3
Question 2					
What is your <u>knowledge</u> level concerning the use of comics for sci. com.?					
Possible answers	Very low	Low	Median	High	Very High
S20 (N = 11)	6	4	1	0	0
W21 (N = 17)	7	8	2	0	0
S21 (N = 9)	4	5	0	0	0
Overall (in %, N = 37)	46	46	8	0	0
Question 3					
What is your <u>confidence</u> level concerning the use of comics for sci. com.?					
Possible answers	Very low	Low	Median	High	Very High
S20 (N = 11)	0	3	2	5	1
W21 (N = 17)	0	1	3	8	5
S21 (N = 9)	0	0	3	5	1
Overall (in %, with N = 37)	0	11	19	49	19
Question 4					
Do you think that the use of comics for science communication is?					
Possible answers	Common	Not common		Never thought of it before	
S20 (N = 11)	3	6		2	
W21 (N = 17)	2	12		3	
S21 (N = 9)	0	7		2	
Overall (in %, N = 37)	14	68		19	
Question 5					
Do you have some prior knowledge (drawing, image editing software) that you think you could make use of during this course?					
Possible answers	Yes				No
S20 (N = 11)	3				8
W21 (N = 17)	8				8
S21 (N = 9)	5				4
Overall (in %, N = 37)	43				57

Sessional results are given in terms of number of response per answer, while overall results are converted in percentage.

3 RESULTS

3.1 Two Examples of Student Works

Figures 1, 2 illustrate two typical work progressions as a function of the workshop number. Both students had hand sketching experience but were novices concerning comics and its design.

The compact nature of a short comic demands that the author first identify the core message that is to be carried out. This is done in a first rough script, in which elements will be considered and either retained or set aside, depending on how necessary they are, how they affect the flow of the story, and how much leeway the storytelling approach allows (see Figure 1 - Workshop #1 and Figure 2 - Workshops #1–3). Graphical elements can already be considered at this stage. In the second step (Figure 1, Workshop #2), a rough draft allows the author to set the pace and tone of the story, determine what information can be fitted on the page, and see how it can be best integrated in the story line. This step usually

leads to several alternate versions. The following steps (Figure 1, Workshop #3–4, Figure 2, Workshop #4) actualize the ideas considered in the preceding step, with final adjustments being made to enhance the story's pace and its readability. Fonts are adjusted, and complex words are replaced by synonyms or simpler wordings. Graphical analogies and metaphors are nearly always embedded into the work (Onomatopoeia in Figure 1–Workshop #three to four, the Star Wars death star vs. our body cells to illustrate respective diameters and objectives in Figure 2–Workshop #4).

It can be precised that even if all works start with a popularized text and end with a piece of comic-based work, the followed path between these two points can vary between participants. This heavily depends on the creative part of the process, and the main idea of the story can be either found very soon or might take a longer time to be identified. It is not unusual that students do not present a first breakdown for the second workshop because they

TABLE 2 | Results of the post-course survey over four teaching sessions.

Question 1 After this course, how would you qualify your knowledge level progression concerning science communication?					
Possible answers	Very limited	Limited	Average	Important	Very important
W20 (N = 12)	0	1	2	8	1
S20 (N = 10)	0	0	4	5	1
W21 (N = 7)	0	0	2	5	0
S21 (N = 5)	0	0	2	2	1
Overall (in %, N = 34)	0	3	30	59	9
Question 2 After this course, how would you qualify your <u>knowledge</u> level progression concerning the use of comics for science communication?					
Possible answers	Very limited	Limited	Average	Important	Very important
W20 (N = 12)	0	0	1	7	4
S20 (N = 10)	0	0	0	5	5
W21 (N = 7)	0	0	0	7	0
S21 (N = 5)	0	0	0	3	2
Overall (in %, N = 34)	0	0	3	65	32
Question 3 After this course, how would you qualify your <u>confidence</u> level progression concerning the use of comics for science communication?					
Possible answers	Very limited	Limited	Average	Important	Very important
W20 (N = 12)	0	0	2	7	3
S20 (N = 10)	0	0	2	3	5
W21 (N = 7)	0	0	0	5	2
S21 (N = 5)	0	0	0	3	2
Overall (in %, N = 34)	0	0	12	53	35
Question 4 Whatever your prior knowledge in arts or media, would you say that during this course, this knowledge has?					
Possible answers	Largely improved		Barely improved		
W20 (N = 12)	10		2		
S20 (N = 10)	9		1		
W21 (N = 7)	5		2		
S21 (N = 5)	3		2		
Overall (in %, N = 34)	79		21		

Sessional results are given in terms of number of response per answer, while overall results are converted in percentage.

did not find their starting point. Presentations from other students and group works in Workshop #2 usually help triggering this process.

3.2 Pre-course Survey

The results from this survey are provided in **Table 1**. The general knowledge level concerning science communication, evaluated in Question 1, is nearly normally distributed around the median answer, with 54% of answers. It appears from the results of Question 2 that the great majority of attendants consider that they have an overall very low or low level of knowledge concerning the use of comics for science communication (46% “Very low” and 46% “Low”). Nevertheless, the answer to Question 3 reveal that this is not necessary linked to a lack of confidence, with 68% of the students reporting a “High” or “Very high” confidence level. Overall, the distribution of answers (from “Very low” to “Very high”) concerning knowledge and confidence are nearly opposite. According to Question 4, 68% of the attendants think that science communication using comics

is not common, and 20% even report having never thought of it before. This shows that even if the use of comics is strongly developing as pointed out in the Introduction section, this use is not well known by postgraduate students. Finally, the results of Question 5 concerning students’ prior skills for this course show that a little more than half of students (57%) could be considered for beginners. From the students point-of-view, comic-based science communication is thus perceived as unknown as its tools and methods, but it nevertheless gives them confidence into its use.

3.3 First Post-course Survey

This survey’s results are provided in **Table 2**. According to the results of this survey, the progression of general knowledge of science communication is mostly considered “Important” with 59% of the answers. Nearly all students estimate that their knowledge level concerning science communication has largely improved (65% and 32% for “Important” and “Very important” progressions, respectively). Compared with the

TABLE 3 | Results of the post-course survey over four teaching sessions.

Question 1		What is the main function of the characters that you designed?			
Possible answers	They directly represent the subject of my research (i.e. an animal for zoology)	They serve as speakers to describe my work			
W20 (N = 11)	7	4			
S20 (N = 10)	6	4			
W21 (N = 8)	4	4			
S21 (N = 4)	0	4			
Overall (in %, N = 33)	52	48			
Question 2		How did you manage scientific information in your work?			
Possible answers	I always clearly transcribed scientific information	I had to modify it to convey my message			
W20 (N = 11)	8	3			
S20 (N = 10)	7	3			
W21 (N = 8)	4	4			
S21 (N = 4)	3	1			
Overall (in %, N = 33)	67	33			
Question 3		Would you say that you wrote?			
Possible answers	A generic story	A story that precisely describes your research	A precise description of your research, but not a story		
W20 (N = 11)	8	2	1		
S20 (N = 10)	4	3	3		
W21 (N = 8)	3	5	0		
S21 (N = 4)	3	1	0		
Overall (in %, N = 33)	55	33	12		
Question 4		To which kind of audience do you think this work is suited (choose all the answers that apply)?			
Possible answers, multiple choices are accepted	University-level, close research area	University-level, any research area	The general public, all ages	The general public, mostly young people	The general public, mostly adults
W20	1	4	5	4	6
S20	3	3	5	1	3
W21	3	3	7	2	1
S21	0	0	2	1	1
Overall (in %, N = 55)	13	18	35	15	20

Sessional results are given in terms of number of response per answer, while overall results are converted in percentage.

reported low level at the beginning of the course, this indicator illustrates a large impact on this considered criterion. Another interesting point is that even if the confidence level was already high before following the course, the respondents report that they nevertheless have a large progression concerning this point. Finally, a global increase in terms of knowledge in arts and media is noted, with only 21% answers reporting a bare improvement in this domain. These results indicate that two of the objectives of such course are achieved, that is, developing transdisciplinary skills and training researchers to science communication. Several students underlined that they had large interest in arts before starting higher education (and being involved into more specialized and intensive teachings) and valued the possibility of combining their interests in different domains.

3.4 Second Post-course Survey

This survey aimed at analyzing from the student's standpoint on how they used comics' features and elements in their work and how they foresee the use of this work. The corresponding results are provided in **Table 3**. The results obtained for Question 1 show that the students choice of a character directly linked to their research or

of a character that would be a simple speaker to describe their research is nearly split half. The analysis of students work by the teachers reveals that the choice of a human-like or non-human character was also nearly parted in half. It is as much the object of science as the person doing this science that are thus used to illustrate a research. Answers to Questions 2 and 3 provide interesting information concerning science and its storytelling. The scientific information was deemed clearly transcribed in their work by 67% of the students, and the remaining 33% had to modify it to convey their message. The "Storytelling" term for the use of comics in science communication seems appropriate with only 12% of works being considered a precise description of a research, but not a story (see Question 3). The answer to Question 4 indicates the general public as the mostly contemplated audience for the work made during the course, with an orientation towards adults. The research area seems not firmly influential on potential university-level readers. Nevertheless, these numbers are weighted by their answer's occurrence since multiple choices were accepted so that they might be biased.

When students were asked if they intended to reuse the work they did during the course and if yes, "In which context?", the

answer was unanimous: 100% of the 33 respondents were willing to reuse this work. The answers to the open-ended question “In which context?” were as follows (ordered in decreasing order of number of occurrences): in a conference presentation, for science communication opportunities or projects, during my PhD defense, in my thesis, to explain my thesis subject to relatives, as a poster for visitors in my lab, for a journal study (supplementary material or graphical abstract), knowledge transfer with partners of a project. This corresponds to the validation of the third objective of the course, that is, to generate concrete contents for science communication. Another open-ended question asked the attendees to provide an adjective to qualify the general tone of their work. The three most cited adjectives were (in decreasing order): humorous, didactic, and documentary. Finally, the last open-ended question was the following: “Would you recommend this course to doctoral students and postdoctoral fellows? If yes, provide a reason why.” The answer was positive for all the respondents, and five reasons why are reported below:

- “Because it allows you to take another look at your doctoral work and to better explain complex notions to people not initiated in the subject. The exchange with other doctoral students is also very beneficial,”
- “This course allows science popularization to be seen in a whole new light,”
- “Because it progresses from an idea to popularize until its complete production,”
- “We think outside the box and the teachers, as well as the exchange with other students, open our horizons. The course has implications for our communication skills beyond the comics-based style,”
- “I would strongly recommend this training to anyone interested in science communication, because it allows you to approach and understand science from another point of view, surely fun but also effective in conveying a message.”

4 CONCLUSION AND PERSPECTIVES

This study described a university course which main objective is to help postgraduate students develop their general interest and skills into science communication using comics as a working medium. All testimonies and survey results confirm the interest of such a science communication course that encompasses several domains. The discovery of other research areas and non-specialist point of views were highly appreciated and stimulated motivation in the course. It appears that comic-based science communication is not well known, but accessible. Within a teaching session, it is possible to obtain high quality works that can be used for various purposes. The participants can appreciate a complete science communication process, from an in-depth work to transform a scientific language to an adapted language until a concrete and tangible achievement. Even if science communication and its outcomes remain difficult to evaluate, as pointed out by Fischhoff (2019), the significant engagement that is promoted by this course allows us to reach effective and concrete results.

One of the stumbling blocks most often mentioned by participants was their initial self-appraised lack of artistic skills or lack of familiarity with traditional or computerized graphic tools, something that is reflected by the data in **Table 1**. Although proper training with classical tools like pencil, pen, and brush would require an extended period, it is quite feasible to guide students through the use of computer-based techniques, including the use of programs especially conceived to draw comics, even with no artistic prior training whatsoever- in just a few hours. This conclusion is shared by Scavone et al. (2019) that point out that it is not only experienced illustrators who can make comic strips, concept cartoons, or even short comic books. The same authors underline that “Even if one does not know how to draw, this should not be a barrier to communicate (...) through the creation of comics.” This is indeed the case in practice according to the presented results and surveys. It is nevertheless underlined that overcoming beliefs of students (and educators) regarding the role of informal reading materials in science education should be systematically considered, since it was identified as a challenge that participants encountered in using comics in Matuk et al. (2021).

A series of short videos detailing and demonstrating such resources is already used in the class, and it would doubtless be beneficial to add a few more, particularly ones focusing on technical problems encountered by students of the class’s first cohorts. From the teacher’s point of view, this course concept can be easily adapted to teach other levels like senior undergraduates provided educators have sufficient knowledge concerning comics and science to answer (quite) miscellaneous questions and support students. A growing number of articles or reports underline the positive effect that creating comics have on student learning and teaching, with examples in various domains like engineering (Barros et al., 2017), management (Barbosa et al., 2017), or operations research (Zamora et al., 2021). Some resources that provide step-by-step instructions for the conceptualization and design of comics that are based on scientific publications are readily available (Friesen et al., 2018; McDermott et al., 2018).

One point that could be also included in future works is cross-cultural communication. Indeed, all participants could be here considered of the same or close culture so that chosen comic images and language will generally increase communication, which could be further studied if the course was taught in various contexts and for various communities including indigenous ones. Nevertheless, a combination of text and images carrying information (or telling a story) is an approach that was developed by several cultures independently and observed as early as 13th century BCE (Egypt’s Book of the Dead), ancient versions of the Persian epic poem *Shahnameh* (see the 14th century Demotte *Shahnameh*, for example), or 11th century Europe (the Bayeux tapestry). The drive to represent reality in a graphic format seems to be a cross-cultural phenomenon, and widespread enough to have a nearly global appeal.

In the coming courses, starting in Winter 2022 session, new surveys will be also designed to refine assessment of fostered qualities and support continuous improvement of the course. Following the two first sessions, a series of workshops has been

opened to a larger community (undergraduate and graduate students, as well as professors) thanks to a science communication grant. One of the most exciting perspectives is the current setup of a book gathering a series of comic-based works. This book will include works conducted within the enlarged community workshops, some of the works produced during the EFD919 course and comics made by professional comics writers on the basis of winning texts from the science popularization contest at Université de Sherbrooke. This book will serve as a unique medium to disseminate science and for science teaching (secondary schools and colleges are especially targeted). Indeed, the question of how produced comics can be further used to support teaching at various levels and the evaluation of their impact will be also considered in future works. Matuk et al. (2021) observed “how the use of a comic book series enabled educators to incorporate multiple literacies and disciplinary lenses into their lessons.” They noted that the use of comics helps to increase the diversity of students likely to engage with science, to bridge science and students personal experience, and finally promote engagement, equity, and diversity. The work carried out during all workshops will thus be valued with an effective transfer of scientific knowledge to the university community and the general public.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for

participation was not required for this study in accordance with the national legislation and the institutional requirements. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

OR wrote the original draft of this article, setup the surveys, and extracted corresponding data. OR and BL equally implemented the course contents and taught the course. ND supported the course setup as an initial pilot course. All authors equally contributed to the review and editing of the submitted version of this article and approved it.

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