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JUMPING TO SCIENCE RATHER THAN POPULARIZING: A REVERSE APPROACH TO UPDATE IN-SERVICE TEACHER SCIENTIFIC KNOWLEDGE

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STRUCTURED ABSTRACT

The need for keeping science teachers up-to-date is stronger than ever, but science curricula and teaching is often still focused on outdated approaches and knowledge. We will discuss some of the strong forces that shape the transformations of knowledge from research to curriculum and to classroom - Chevallard (1991)'s Didactical Transposition (DT) - and propose a different approach specifically for teacher professional development. Our research question is: can a different approach reduce detrimental effects of these processes on teacher development and their educational practice? We will bring arguments for an inverted approach that could improve or circumvent DT. We then present the Jump-To-Science (JTS) project developed since 2006, and discuss some results on the basis of on-line questionnaires administered in 2013 (39 responses) and 2019 (47) addressing teachers' use and perception of JTS. The readership of JTS has regularly grown over the years, suggesting relevance. Respondents mentioned JTS's importance for their teaching and their awareness of changes in biology. The use of primary articles increased 2013-2019. Teachers' engagement in the use of primary literature for themselves and for their students is worth noting and promising (effectively using the opportunity to jump to science). Taken together, the results suggest that JTS succeeds in empowering an important fraction of the biology teachers to read authentic scientific research, circumventing the knowledge transformation effects of DT. This might support a progressive move towards more up-to-date and active learning strategies by confronting learners with more authentic sources.

Background: Chevallard's Didactical Transposition (DT) research shows that scientific knowledge as it percolates from research into classrooms is transformed before it can be used by teachers. It loses the context in which it was elaborated and a large part of its uncertainty, and becomes definitive and generalized in order to be taught. The knowledge teachers effectively use has inspirational thrust, is craft legitimated and locally adapted, proximal and available (Huberman,1983), in stark contrast to classical academic literature.

Purpose: This contribution discusses a new approach to address the difficult question of keeping in-service secondary school teachers up-to-date with the continuous progress of biology research. Our research question is: can a different approach reduce most of the detrimental effects of the growing distance between taught biology and research biology on teachers' development and their educational practice?

Setting: First we will bring arguments for an inverted approach that could improve or circumvent DT. We then propose a sample project in a local setting (Geneva, Switzerland) that implements this approach developed over 15 years, and discuss some results. Understanding these knowledge transformations as inevitable transposition steps rather than bad popularization enables a new approach: rather than attempting to popularize differently *down* to teachers, the Jump-To-Science (JTS) project proposes helping teachers *up* to scientific knowledge directly in its most authentic available form: in scientific journals. It also takes into account the characteristics of knowledge that research identifies as effectively used by teachers: it carefully shares teachers' values, and gives tokens of teaching experience, and highlights the practical usability in classrooms.

Methods: A 2019 survey study evaluates the perceived use and usefulness of the JTS publication using descriptive or exploratory statistics. We received 47 responses from a total subscriber population of 443. We present some frequencies for all respondents and compare these to results from an earlier 2013 survey (N=39). We then focus on the secondary teacher subpopulation in the 2019 sample (N=27). Correlations were computed with Spearman's rho. We conducted a principal component analysis on seven questions with 4-point response items and identified three dimensions of use and usefulness explaining 72.4% of the variance. A K-means procedure that is appropriate for ordinal data was used to create a typology of these teachers and we identified an interesting three groups solution.

Results: JTS has been published since 2006 and readership regularly increased (currently 443), an indicator of perceived relevance. 83% of respondents to the 2019 survey (N=47) consider that JTS is important for their teaching and their awareness of changes in biology, up from 60% in an earlier 2013 survey (N=39). 73% believe JTS has changed the approach of some chapters in their teaching, compared to 60% in the 2013 survey. Use of original materials reaches 86% in 2019. Cluster analysis of the 27 secondary teacher sub-population who responded reveals different types in the use of JTS. Some moderately or strongly engage JTS in the use of external resources for themselves and for students, effectively using the opportunity to *jump to* science, while others engage JTS for teaching improvement but rarely read original articles, using JTS as a form of teacher-adapted popularization. The most interesting correlation in this subset (N=27) is that teachers who follow up primary literature discussed in JTS articles for themselves also offer some of these to students.

Conclusions: Our exploratory analysis suggests that there are different types of engagement in primary literature: it is either read and distributed as resources for student learning, read for teachers' own use, or ignored (teachers rely on JTS's summaries and comments).
Taken together our results suggest that JTS succeeds in empowering an important fraction of the local biology teachers to read authentic research results, which can be interpreted as circumventing the knowledge transformation effects of TD. This could give rise to a slow evolution from a classical transmissive style (teacher informs, summarizes, transposes and diffuses knowledge) towards more up-to-date and active learning strategies by confronting learners with more authentic sources.

Keywords: *Teacher training; science education, didactical transposition*

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1 INTRODUCTION

This contribution discusses a new approach to address the difficult question of keeping in-service secondary science school teachers up-to-date with the continuous progress of biology research and teaching. The need for keeping science teachers up-to-date is stronger than ever since science curricula and teaching often focus on outdated approaches and knowledge. At the same time, the world students have to face is becoming more complex and with social media development, the limits between truth, fiction and deliberate misinformation are ever more difficult to discern. We will discuss some of the strong forces that shape the transformations of knowledge from research to the curriculum and to classrooms, and propose a different approach specifically for teacher continued training or professional development. First, we will bring arguments for an inverted approach that could improve or circumvent Chevallard's Didactical Transposition (DT) (Chevallard, 1991). We then propose a sample project (Jump-To-Science (JTS)) that implements this approach, developed over 15 years, and we will discuss some results.

2 RESEARCH BACKGROUND

Didactical Transposition (DT) theory (Chevallard, 1991) holds that knowledge, as it percolates from research into classrooms is transformed before it can be used by teachers, losing the context in which it was elaborated. A large part of the bounded uncertainty that is characteristic of scientific knowledge becomes definitive and generalized in order to be taught. Popularization has similar effects and both contribute to disconnect science teachers from current science research. Which in turn leads to students being ill-prepared to understand the issues that bioscience progress raises in society. Chevallard (1991) calls "monuments" traditionally taught knowledge that was once alive but that does no longer have explanatory power or relevance to the student's world, but that curricula, teachers and social recognition require students to know. A typical example is the taste map on the tongue, where connection with the original research by Hänig (1901) (figure 1) showing subtle differences in sensitivity densities has been transposed in textbooks into various taste maps that have clear definite borders, losing the methods by which this data has been produced and the uncertainty of the original research. Relatively recent research shows that "contrary to popular belief, there is no tongue 'map'" (Chandrashekar, Hoon, Ryba, & Zuker, 2006, p. 288).

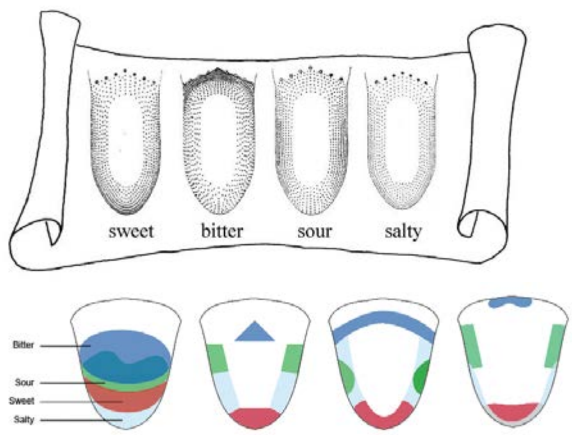

Fig. 1. Top) The original research: taste map according to Hänig (1901). Bottom) Typical examples of taste maps in various textbooks.

Our research question is therefore: can a different teacher development approach reduce most of these detrimental effects on teacher development and–their educational practice? Our answer is to invert the approach in order to circumvent DT. Disciplinary biology knowledge taught in schools is very rapidly expanding. Much knowledge students receive during secondary school was not known or not taught when senior teachers currently in post got their degree. These teachers had to learn and transpose for their students great expanses of bio scientific progress, such as genetics, PCR, sequencing, genetic engineering, neuron physiology, mitochondria, cell membrane structure, cancer mechanisms, clonal selection and most of immunology, allergy, neuroscience and neuroimaging, FMRi, etc. For example, in the 80s, recently trained teachers taught students that the human genome was made of millions of genes, the single sequence that could be presented was part of the protein insulin (30+21 amino-acids). During their career, they had to update to research progress that made the headlines: in 2001, a single full human genome was published, offering 3 billion bases, freely accessible – even in schools with a simple internet connection. The current gene count is around 20,500, and thousands of human genomes are available for comparison.

In 1995, the Swiss people voted to accept genetic engineering, and went on to develop in a few years a strong anti-GMO feeling, which in both cases highlights the need for a good understanding of the science involved and the pressure on teachers to keep up-to-date. But science goes on: genetic progress reveals susceptibility to ever more illness (Lappalainen et al., 2013), finds criminals by their relatives in genealogy databases (Erlich, Shor, Pe'er & Carmi, 2018), identifies how genes impact the cultural influence on educational outcomes (Kong et al., 2018). Recent neuroscience research produces neuroimaging evidence (including FMRi) about various human brain processes, such as extracting and viewing on a computer the face subjects view (Chang & Tsao, 2017), identifying natural images (Kay, Naselaris, Prenger, & Gallant, 2008), or nouns (Mitchell et al., 2008), predicting decision-making (Haggard, 2008), potentially controlling revenge (Klimecki, Sander, & Vuilleumier, 2018), and learning to control pain (deCharms et al., 2005). Many of these have received much attention in the media, and often raise controversies in the general public, that challenge school biology. How can teachers trained 35 years ago be updated with this knowledge when faced with students' questions...?

While the need for in-service training should be easily perceived by teachers, authorities often report difficulties in reconciling the perceived needs of school management, unions, teachers, and pre-service training organizations. Research shows that many innovative, well-thought professional development projects have had difficulties in producing lasting changes in the classroom (e.g. Osborne, Simon, Christodoulou, Howell-Richardson, & Richardson, 2013). While excellent popularized science is available in the form of news in high profile scientific journals such as *Science*, *Nature*, or in magazines such as *Scientific American* or *La Recherche*, scientists often complain that the knowledge offered to young students is often outdated or poor, and PISA results across Europe (OECD, 2014) show there is room for improvement in the scientific knowledge students effectively have acquired in schools and can refer to when deciding.

Research about the popularization processes (Lombard & Weiss, 2018) can explain why sensationalist definitive conclusions are presented (e.g. "the gene for xxx has been found") without the balanced discussion of limits and perspectives which is characteristic of scientific knowledge. Similarly, DT process (Chevallard, 1991) depletes school knowledge of important scientific aspects. Knowledge goes through many selection and change steps from research to classrooms (publication, educational authorities, curricula, schoolbooks, etc.). At each transition some aspects wane, or disappear, and others develop, leading to knowledge in schools being predictably transformed before entering the classroom and becoming "true" (figure 2). In fact, DT shows that, beyond simplification, different forms of knowledge develop in different cognitive ecosystems. For example, social context is often lost from research to publication, the degree of uncertainty and controversies tend to disappear when authorities define curricula, methods necessary to understand the potential and limits of research findings are rarely treated in class (Kampourakis, Reydon, Patrinos, & Strasser, 2014).

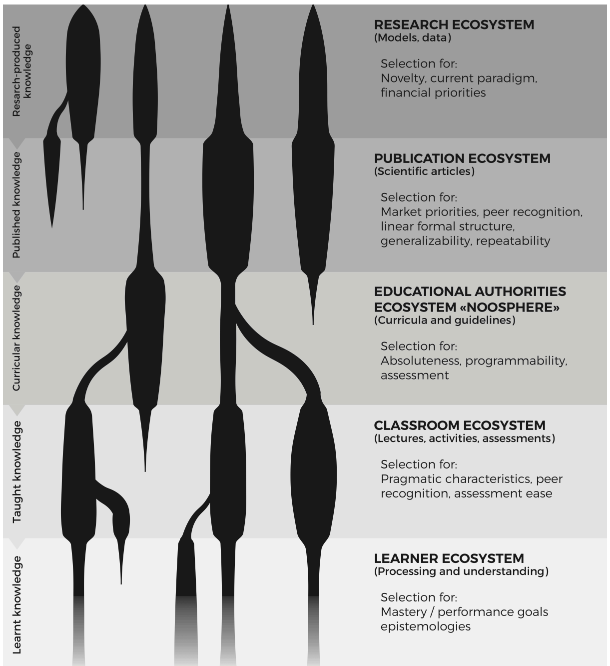

Fig. 2. Knowledge goes through many selection and change steps from research to classrooms; some aspects wane, or disappear (vertical stripe narrows), others develop (strip widens) leading knowledge in schools to being predictably transformed (Lombard & Weiss, 2018). Figure by V.Widmer

Understanding these changes as inevitable transposition steps rather than bad popularization enables a new approach: rather than attempting to popularize differently *down* to teachers, we propose helping teachers *up* to read scientific papers and access scientific knowledge directly in its most authentic available form: in scientific journals such as *Nature*, *Science, Cell*, etc. After all, in Geneva, all secondary science teachers have a Master degree[1] and also exposing high school students to primary literature has been successfully proposed (e.g. Hoskins, Stevens, & Nehm, 2007). Huberman (1983)'s analysis of knowledge really used by teachers in schools shows it has to be felt as having inspirational thrust, being craft legitimated and locally adapted, proximal and available. This is in stark contrast to classical academic style, which in part explains why teachers often lose contact with the scientific literature they were attuned to during their studies.

In order to help senior and young teachers to keep in contact with original scientific literature and research in their field, the Jump-To-Science (JTS) project was created in 2007 under the name Bio-Tremplins. JTS is an electronic publication sent (email) to 443 subscribers once or twice monthly, and archived on a platform at Geneva University. It highlights a selection of recent research relevant for schools (biology, medicine, and other sciences) from *Science*, *Nature*, *Cell*, *PNAS*,… with comments about the possible implications for science teaching.

JTS does not try to popularize better than what professional science writers produce, rather, it is an appetizer and a springboard (hence the moniker "Jump-To-Science") towards authentic scientific articles. JTS takes an inverted approach to updating teacher's scientific knowledge by i) selecting in primary literature research that is relevant for teaching biology, ii) showcasing in what the research is new and changes classically taught knowledge, iii) highlighting the educational implications, iv) encouraging teachers to refer to the original article, v) and facilitating access to the original articles. The editorial style adopts a high level of scientific communication - adapted for teachers who have an MA in science. At the same time, it takes into account the characteristics of knowledge that Huberman (1983) identified as efficient in knowledge use by teachers: it carefully shares teachers' values (such as inspirational thrust), and gives tokens of teaching experience (instrumentality, craft legitimation, local adaptiveness, availability, …), and highlights the practical usability in classrooms. The distribution by email reduces the perceived distance (proximity).

3 METHODS AND DATA

JTS subscribers include 174 (87%) of the approximately 200 local secondary school biology teachers. In 2019, an online line questionnaire addressing teachers' use and perception of Jump-To-Science (JTS) was sent to all subscribers, N=64 responded, and N=47 were fully completed. 14 (29.8%) were higher secondary teachers from Geneva, 6 (12.8%) lower secondary teachers from Geneva, 7 (14.9%) secondary teachers from other places, 13 (27.7%) other teachers (university or teacher trainers) and 7 (14.9%) not teaching or other (e.g. researchers and trainees). A subset of 27 secondary teachers were used for most analysis. Of these, 60% were male and 30% female, 10% declined to answer. Median age group is 48 and shows interest from many senior teachers. Some simple descriptive results were also compared to an earlier online questionnaire administered to all subscribers in 2013 (N=39). Questions were self-developed, primarily to understand how the JTS publication is used and perceived. Seven 4-point scale questions targeted specifically the perception of the usefulness and the use of JTS (tables 1 and 2 for a summarized translation of these).

This self-selected sample (N=47) is not representative of the subscriber population allows identifying interesting patterns in the data that could be further investigated in a confirmatory study. Therefore, the data was mostly used for descriptive or exploratory statistics. For the secondary school teachers' sub-population (N=27), we conducted a principal component analysis with seven items (table 1) in order to detect underlying components and found a satisfactory varimax rotated 3-factor solution with eigenvalues > 1, explaining a total of 72.4% of the variance (factor 1 32.3%, factor 2 23.8% and factor 3 16.3%). We computed two scales: (i) *Importance of JTS for teaching* is the mean of "JTS's importance for teaching", "JTS's impact on teaching", "integration of JTS material in classes" (Cronbach's alpha = .77) and (ii) *Using JTS for deep knowledge* which is the mean of "reading original articles" and "diffusing original articles" (Cronbach's alpha = .74).

We also created a typology for the same teachers' population with respect to their perception of use and usefulness of the Jump-to-Science platform (table 2). Individuals were clustered with a K-means procedure, appropriate for ordinal data. These variables discriminate groups well (F values in the Anova table are < 0.05), but distances between final cluster centers are not very strong, i.e., 2.1 between clusters 1 and 2, 2.85 between clusters 1 and 3, and 2.1 between clusters 2 and 3.

4 RESULTS

Each publication of Jump-to-Science (JTS) highlights a research advance relevant to secondary teaching, showcases selected research articles, then offers access to them for the members. By putting into perspective its implications for education and providing a taste of the content, it encourages readers to jump to the original article. This regular encounter with research aims to infuse the complex and nuanced characteristics that define science knowledge, bypassing some DT steps and leaves to teachers the opportunity and the responsibility of transposing it into their classrooms. Having the university via its JTS encouraging teachers to read primary literature is also intended to boost their professional self-image as scientists.

[1] In Geneva, secondary I and II teachers follow the same training curriculum and are required to have a MA in the subject they teach.

JTS has been published since 2006 and the number of its readers has continually grown even with teachers leaving professional life, which is a first indicator of perceived relevance. 91.5% of the respondents in the 2019 survey (Valid N=47) read JTS either sometimes or always (57.4%). 73% believe that JTS has changed the approach of some chapters in their teaching; up from 60% in 2013. 86% consider that they have included information from JTS into their teaching. 82% declare having (always or sometimes) read the original scientific articles mentioned in JTS. 78% (up from 68% in 2013) answer they have (sometimes or rarely) distributed original articles mentioned in JTS - or at least extracts - to students. 92% of respondents totally or somewhat agree that the tone of the communication addressed to the experts gives them the feeling of being "recognized as a scientist in my discipline." In sum, respondents to the survey mention JTS's importance for their teaching and awareness of changes in biology. They believe that the use of original literature is important. All numbers did increase from 2013 to 2019.

Let us now look more closely at the secondary biology teacher population of the 2019 survey (N=27). Few teachers (3, 11.1%) never read original articles, 8 (29.6%) rarely do so and 15 (55.6%) sometimes do so (1 no response). 6 (22.2%) teachers never redistribute articles, 12 (44.4%) rarely do so and 6 (22.2%) do it sometimes (3 are missing). 6 teachers (22.2%) state that JTS had little influence on their teaching and only one teacher declares "no influence. 8 teachers (29.6%) mostly and 9 (33.3%) fully agree that JTS did have them change certain "chapters" of their teaching. This means that some teachers use the opportunity to "jump to" science while more teachers just use JTS as a resource to improve their teaching, i.e. they never or rarely read original articles but use JTS as a form of teacher and learner adapted popularization. A minority use the resources offered but consider the impact of JTS on their teaching moderate.

An interesting correlation (Spearman's rho = 0.6, p=<0.01) shows that teachers that engage JTS in the use of primary literature for themselves tend to give original articles to students ("Jump-to" effect). A more obvious positive relation is between integration of JTS materials in class and the perception that JTS made them change some of their teaching (rho = 0.51, p=<0.01). There is no significant relation between the importance of JTS for teaching scale and using JTS for deep knowledge scale.

In the same logic, a principal component analysis explaining 72.4% of the variance shows 3 interesting factors: (i) engagement of JTS for teaching improvement, (ii) use of primary literature for themselves and for students (Springboard effect), and (iii) being recognized as a scientist.

Tab. 1. Principal component analysis of seven items

Extraction/rotation method: Principal Component Analysis/ Varimax with Kaiser Normalization. 3 components extracted.			
	Engagement of JTS for teaching	Use of primary literature	Being recognized as a scientist
Did you read the original articles (Science, Nature, etc.) mentioned in JTS?	.200	**.856**	-.146
Did you distribute the original articles mentioned in JTS to students or others in your professional activity?	.240	**.851**	.062
JTS is important for the quality of my teaching.	**.869**	.094	-.013
JTS made me change the approach of certain chapters in my teaching or my profession.	**.727**	-.189	.356
I sometimes integrate information from JTS into my teaching / my professional activity..	**.796**	-.332	-.060
With this type of communication, I feel recognized as a scientist in my discipline.	.160	.056	**.779**
Do you regularly read JTS?	**.510**	-.127	**-.609**

A K-means cluster analysis of the 27 secondary teachers in the 2019 survey allowed us to identify three types of teachers (table 2). A first type labelled "big change" considers that JTS is important for the quality of teaching and made them change the way they teach. They sometimes read original articles and distribute them in class. The largest "some change" type (about half) considers JTS important for teaching like the first type, but makes less use of it, e.g. rarely read original articles and rarely or never distribute them in class. A third "little influence" type of 5 teachers judge JTS somewhat useful for their teaching, but do not acknowledge any influence on teaching. However, they do use it as a resource.

Both the principal component and the cluster analysis show that there are different patterns of engagement of JTS by secondary biology teachers. Three types of users emerge: (i) JTS as an incentive to change and to *jump to* science (ii) JTS as an important resource for teaching, and (iii) other, i.e. possibly teachers that use JTS for their own general knowledge, or out of curiosity. This might also be related to the different needs of teachers according to the age of their students. In addition, most secondary teachers find JTS a very useful resource and read it always, but this may be an effect of self-selection of the respondents.

Tab. 2. Use and usefulness of Jump-to-Science

Typology of secondary teachers (K-means cluster, N=27, 1 missing case)				
Items (response items without answers were removed). Color codes visualize dominating agree (green) and disagree (red) values for each respondent type.		Type 1="big change" N=7	Type 2="small change" N=14	Type 3="little influence" N=5
JTS is important for the quality of my teaching.	2 Partly agree	0	2	2
	3 Mostly agree	1	6	2
	4 Fully agree	6	6	0
JTS made me change the approach of certain chapters in my teaching or my profession.	2 Partly agree	0	3	3
	3 Mostly agree	2	6	0
	4 Fully agree	5	4	0
I sometimes integrate information from JTS into my teaching / my professional activity.	2 Partly agree	0	0	2
	3 Mostly agree	2	10	3
	4 Fully agree	5	4	0
Did you read the original articles? (Science, Nature, etc.) mentioned in JTS?	1 Never	0	3	0
	2 Rarely	0	7	1
	3 Sometimes	7	4	4
Did you distribute the original articles mentioned in JTS to students or others in your professional activity?	1 Never	0	5	1
	2 Rarely	2	8	2
	3 Sometimes	4	0	2
JTS raised my awareness about the research done at Geneva university?	1 Disagree	1	0	0
	2 Partly agree	2	0	1
	3 Mostly agree	4	5	2
	4 Fully agree	0	9	1
Do you regularly read JTS?	3 Sometimes	2	5	3
	4 Always	5	9	1

Overall teacher perceptions from responses in the survey can further be illustrated by a few quotes.

> *"[JTS] gives me inspiration and concrete ideas on how to use these scientific 'news' in my classes, allows me to bring 'true' information to my students."*
> *"[JTS is] a window on science as it is practiced by its agents."*
> *"JTS is unique! There is a lot of good popularized science, but JTS is the only publication that helps us transform our lessons in the classroom."*
> *"JTS develops a spirit of openness and a critical sense which I find essential in teaching as in all scientific activity. By regularly receiving this research news, I feel supported and encouraged in my teaching activity. "*

5 DISCUSSION AND CONCLUSIONS

The project presented here has developed over a decade and a half and the results from JTS can be seen as a proof-of-principle confirmation that such new inverted approaches for keeping teachers up-to-date can be developed. Survey responses of all respondents (N=47, e.g. including teacher trainers, academics and teachers-in-training) highlight the importance of JTS for awareness of changes in biology, the important reading rate (91.5% sometimes or always) and agreement on the use of primary literature (78%) for teaching, increasing from 2013-2019. These survey results are promising, but without data about non-respondents, nor a solid measure of what teachers implement in their classrooms, more research is needed in order to confirm these results.

The most interesting correlation in the secondary teacher subset (N=27) is that teachers who follow up primary literature discussed in JTS articles for themselves also offer some of these to students. The typology suggests that there are different types of engagement in primary literature: it is either read and distributed as resources for student learning, read for teachers' own use, or ignored (teachers rely on JTS's summaries and comments). Taken together, these results suggest JTS succeeds in empowering to different degrees an important fraction of the approximately two hundred local biology teachers of which 174 are subscribed to JTS to read authentic research results, which can be interpreted as circumventing the knowledge transformation effects described by Didactical Transposition (DT) theory. In this way, JTS contributes to a slow evolution from a classical transmissive style (teacher informs, summarizes, transposes and diffuses knowledge) towards more up-to-date and active learning strategies by confronting learners with more authentic sources.

This project shows synergistic effects on professional development, helping to raise teacher awareness of their training needs, a recognized obstacle for volunteer in-service training. The fact that results start appearing after many years confirm - without surprise - that changing teacher professional habits must be considered in a long-term perspective.

Developing projects inspired by this reversed approach on a larger scale, and analyzing the effective practices of teachers and the effects on student learning is a promising research venue: JTS could target only secondary II teachers with an MA. However, our results suggest that no restriction is needed as numerous secondary I subscribers mentioned that JTS stimulates their curiosity and professional involvement.

The requirements in terms of skills needed for leading such projects are multiple (cutting-edge science, DT, teacher values, school system,…) and could limit its generalizability. The relevance of this reverse approach could be considered for other sciences, e.g. physics, chemistry and earth sciences as well as most humanities and social sciences.

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