TEACHING PHD STUDENTS EFFECTIVE COMMUNICATION OF SCIENTIFIC RESEARCH

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Abstract

It is of vital importance that researchers learn how to communicate their scientific findings in an effective and precise manner. For this reason, graduate programs in science and engineering would benefit from structured teaching of communication skills. In this paper we outline the Assertion-Evidence structure for design of presentation slides, which has formed the basis for a sequence of communication workshops directed at graduate students and researchers in the United States and Europe. In particular, we report on the effect of teaching scientific communication skills to 68 PhD students and postdocs through an intensive, three-day workshop held in Norway in March 2009. Self-assessments of the individual learning outcome indicate a statistically significant improvement in how the participants prepare and deliver scientific presentations to peers and the public.

Keywords - scientific presentation, scientific writing, communication, graduate students

1 RESEARCHERS NEED TO LEARN HOW TO COMMUNICATE SCIENCE

It does not matter how important or brilliant your research is, if you are not empowered to communicate your results and describe the consequences thereof in an effective manner. For this type of communication, it is crucial that the information is presented at the right level of detail and in a reference frame that fits the audience. Learning how to present scientific results, in writing as well as in speech, is therefore an important part of the education of researchers.

Unfortunately, the teaching of presentation and writing skills are often neglected or kept at a minimum in traditional PhD programs. The general approach seems to be that of “on the job training”, in which the students acquire such skills from their supervisor in the tradition of a master-apprentice relationship. Although this approach *can* work very well, it is highly unpredictable and does in many cases not offer the quality and precision required in other aspects of the student’s work.

There exist a large number of textbooks and courses that aim at teaching how to design and deliver presentations, and how to write different types of documents. However, the majority of such offerings are primarily focused on sales presentations and business documents. It is rarer to find serious attempts at addressing these skills in the context of scientific research.

Some universities in the United States, such as Ohio State University [19], the University of Wisconsin-Madison [15], and Colorado School of Mines [13], offer their graduate students semester-long courses on communication of research. Although being of high quality, only a fraction of the students benefit from these courses. As an example, only 38 students took the communication course at the Colorado School of Mines in the period from 2000 to 2004.

Other institutions try to reach a larger number of students through workshops, typically organized through their graduate schools. For instance, the University of Texas at Austin [8], Texas A&M University [16], the University of California-Davis [18], and the University of Illinois at Urbana-Champaign [12] have all used this approach. A potential challenge for these workshops is the fact that they are open to graduate students from all colleges, thereby facing a very broad scope of writing

ranging from the humanities to the sciences. In the end, the advice offered in these workshops may easily be too general for students in science and engineering.

Our focus is on a workshop format aimed at teaching communication skills specifically to science and engineering students [6]. This workshop, which contains components on scientific presentation and scientific writing, has been developed over more than 20 years by associate professor Michael Alley at Pennsylvania State University, formerly at Virginia Tech. Accompanied by two books published by Springer-Verlag [1] [2], this workshop has been successfully tested on more than 500 students at Pennsylvania State University, the University of Illinois at Urbana-Champaign, the University of Oslo, the University of Texas at Austin, and Virginia Tech, as well as at a number of research laboratories in the United States and Europe. The effectiveness of this workshop format relies heavily on pre-workshop assignments and hands-on training sessions, in which the students both give and receive oral feedback on their presentations and documents.

Simula School of Researh and Innovation (SSRI), which is the educational unit at Simula Research Laboratory located close to Oslo, Norway, hosts a large number of PhD students and postdocs in the areas of information technology. One of SSRI's goals is to provide training outside the traditional university curriculum that can significantly improve the competence of the students. Simula and professor Alley have since 2003 developed a strong collaboration concerning courses on scientific presentation and writing. From 2008, these courses are arranged on an annual basis for SSRI's students.

In this paper, we describe how the workshop format developed by professor Alley formed the basis for the three-day long, national event "Communicating Scientific Research". This workshop, which was held in Oslo, Norway in March 2009, provided a successful training of 68 participants, mainly PhD students from across the country. In addition to teaching the participants new and improved skills, the event provided an opportunity of measuring the effectiveness of the techniques discussed in the workshop, as well as the effectiveness of the training itself. Given this opportunity, we faced three important questions:

1. Could a communication workshop be taught to a sizable number of graduate students?
2. Would a sizable number of Norwegian graduate students be interested in committing the time and energy to such a workshop?
3. Would such a workshop lead to significant improvements in communication skills of those participants?

In the next two sections we describe the process from a vague idea to the actual implementation of the workshop. Thereafter, we present our observations based on the participants' systematic self-assessment at different stages of the learning process.

Further details on the national workshop and the assessment of its effect can be found in the report [3]—see also [4].

2 FROM AN IDEA TO A VIBRANT WORKSHOP

In the spring 2008, during that year's courses in scientific presentation and writing held locally at Simula, the idea of offering a *national* workshop to Norwegian PhD students surfaced. This idea was founded on the positive response from course participants over several years, and from having observed significant improvement in the presentation and writing skills of graduate students who have completed the training. Assessment of earlier installments of the courses in the United States has concluded that more than 95% of the participating students strongly agreed or agreed that the training was a valuable experience [6].

Following the initial idea, discussions concluded on a set of principles that we intended to use as a basis for a national event. First, we would invite participants from all Norwegian universities that award PhD degrees in science and engineering. Secondly, we would like to have a representable spread of students based on geography, scientific topics studied, and gender. Moreover, we felt that it would be important to offer the training at minimal cost for the participants, mainly to avoid the situation that potential participants would dismiss a communication course in favour of participating in conferences in their own research fields. Because most students have limited funds for participation in external events, this type of choice would have posed a tough challenge for students. As a consequence, we decided to seek funding that would allow us to keep the instruction, accommodation and meals free of

charge to the participants. Because this policy would require a substantial sponsorship, it was also natural to limit the cost by choosing the compact format of a workshop in which lectures and hands-on training sessions would be combined into an intensive and immersive experience.

In Norway, education is primarily a public responsibility. The Research Council of Norway (RCN) is a vital factor in research education, through research grants and scholarships for the PhD and postdoctoral levels. Therefore, the natural first step was to approach RCN for funding. The council applauded our idea, but it was quickly realised that there were no suitable mechanisms in the RCN for financial support of this type of event.

Given the strong relations between Simula and some of the major industrial companies in Norway, we decided to pursue monetary support from some of these partners. Three large companies were invited to join the project as sponsors. Of these three, StatoilHydro and Telenor decided to contribute 250,000 NOK, or roughly 29,000 Euro, each. In the following weeks, important contributions were also made by the Faculty of Mathematics and Natural Sciences at the University of Oslo, the Norwegian Defence Research Establishment, and IT Fornebu. The total budget then increased to 705,000 NOK, which amounts to slightly less than 82,000 Euro.

Given the amount of available funding, we decided that the event should cover three days of plenary lectures and group-based training sessions. With this format, we would be able to accomodate 68 participants in total at Voksenåsen Kultur- og Konferansehotell, a high-quality resort located just outside the city center of Oslo.

2.1 The workshop components

The national workshop contained the following three components:

1. *Scientific Presentations* is an 11-hour component designed to help scientists and engineers make their research presentations more understandable, memorable, and persuasive. This component, which includes a preparation assignment, features critique sessions in which each participant makes a presentation and receives a critique from the instructor and other participants. The component has four goals: (1) to teach participants effective strategies for structuring their research presentations; (2) to have participants completely rethink the design of visual aids (and, in particular, presentation slides); (3) to have participants analyze what would be the best delivery style for themselves; and (4) to have participants learn and practice strategies for answering questions about their research. The techniques discussed in this component have wide application, but the examples and discussions assume that the target audience consists mainly of peers.
2. *Communicating Science to the Public* is a two-hour component helping research scientists to communicate their work to government officials, non-technical managers, and the general public. The main goal of the component is to teach scientists how to lead a non-technical audience up the mountain of their research so that the audience reaches what Richard Feynman called an “honest” understanding of the science. The component has four goals: (1) to teach participants how to craft the story of their work; (2) to teach participants how to select wording for this story; (3) to teach participants how to select and design the key visual evidence that illustrates the story; and (4) to teach participants how to develop a delivery style that will connect with the audience and establish credibility.
3. *Scientific Writing* is a four-hour component designed to help scientists and engineers improve the way that they document their research in journal papers, conference publications, dissertations, and research reports. The component, which includes a preparation writing assignment, has three goals: (1) to teach participants the differences between strong and weak structures, language, and illustrations in research documents; (2) to make the writing process more efficient for participants; and (3) to give the participants a jumpstart on a research document that they want to write.

In order for the compact workshop format to be successful, it is essential that the participants devote time to preparation assignments during the weeks preceding the event. These assignments form the basis for the hands-on training during the critique sessions. The assignments and the critique sessions are described in more detail in section 3.

2.2 The assertion-evidence structure for presentation slides

The workshop components Scientific Presentation and Communicating Science to the Public were based on an approach to presentation slide design that challenges traditional design rules. These traditional rules typically lead to text-rich slides with bullet lists and headlines consisting of a phrase or a keyword. The functional design of PowerPoint and similar software products inherently support the traditional conception of slide design, which thereby has dominated technical presentations for two decades.

The alternative style taught in the national workshop is known as the *Assertion-Evidence (A-E) structure*. This structure puts special emphasis on the use of visuals, minimal amount of text, and headlines forming a succinct sentence assertion for each slide [5][7][10]. The visuals, possibly complemented by carefully selected text fragments, act as evidence supporting the assertion. This technique lends itself naturally to disciplines that are rich on photographic evidence, such as geology and biology, but also supports equally well presentations containing graphical exposition of numerical data, such as in mathematics and physics. Perhaps less obvious, but nonetheless equally valid, the A-E style of slide design can be effectively used also in presentations for which the access to visual components might seem difficult. In those situations, the main challenge is to rethink one's assumption of visuals. For instance, one might look for simple diagrams and schematics to illustrate software engineering processes, or think of mathematical equations as imagery where color-coded annotation can be used to highlight relationships between different entities. A comparison of the common-practice structure and the A-E structure appears in Fig. 1.

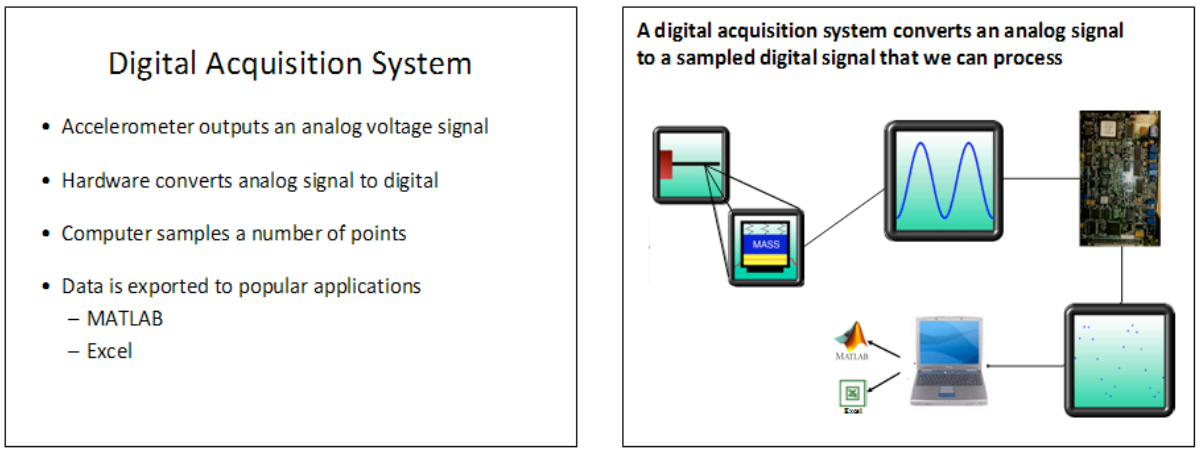

Fig. 1. Comparison of a common practice slide (left) with an A−E slide (right). The A−E slide has only half the words, but helps the speaker communicate the most important assertion for that portion of the presentation is more understandable and memorable way.

Slide design using the A-E structure calls for an increased effort from the presenter when compared to the traditional "bullet list" design. This extra effort is caused by the construction of strong assertion headlines, the preparation of visual evidence, and the lack of support for such slide design in PowerPoint and similar software. Experiences from teaching students to use the A-E approach indicate a considerable initial resistance due to the extra effort from the presenter [14]. However, the clarity and effectiveness of the resulting presentation should in theory outweigh the extra investment [11]. This assumption is often confirmed when listening to presentations performed by presenters who have worked with the A-E style for some time. First of all, the investment needed to establish strong visuals and practical solutions to the implementation of slides can be amortized over several related presentations. Moreover, it appears that the process of establishing assertion headlines and the need for practising the delivery of slides with few text entries help the presenter in making a clear case of the content to the audience.

Also for the national workshop we experienced initial restistance among the participants when it came to adopting the A-E structure for their own presentations. Comparing the slides that the participants submitted for the first two preparation assignments, that is, without and with the A-E slide stucture, we could see a relatively strong degree of adoption of the new technique [3]. After having received lectures on the A-E strucure as part of the workshop, this trend seemed to increase as the participants

made their presentations in the critique sessions. In general, at the end of the workshop the participants were able to create presentations that were superior to what they had created before. We did also a post-workshop comparison with a large number of presentation slides prepared by graduate students from a highly ranked engineering college in the United States. This comparison revealed that the participants in the Norwegian national workshop produced better results than a representative sampling of U.S. graduate students [3].

3 ORGANIZATION AND IMPLEMENTATION OF THE WORKSHOP

One of the essential questions we faced when we designed the workshop was if a sizeable number of Norwegian PhD students would be interested in committing the time and energy to a workshop focusing on the communication of their research. This question addresses both the importance that Norwegian graduate students assign to the skills of communicating their research, and the support that these students perceive that they are currently receiving to attain those skills. This section describes the interest we experienced that PhD students have in learning the craft of communicating research, and the level of commitment that the selected participants showed when taking part in the workshop.

Early January 2009, we distributed over 1900 information brochures to potential participants, inviting them to register to attend the workshop Communicating Scientific Research. This invitation referred to a dedicated website [17] presenting the details and practicalities about the workshop.

The invitations were aimed at the PhD students enrolled with the engineering and science programs at all the Norwegian universities, and by making follow-up contact directly with the institutions, we tried to make sure that the information reached the target group. In practice, the invitation reached almost all Norwegian PhD students in engineering, the information sciences, the earth sciences, the physical sciences, and the life sciences.

3.1 The application pool and selection of participants

At the application deadline four weeks after the announcement, we had received 232 applications from potential participants representing all the Norwegian universities and a wide variety of disciplines. Fig. 2 shows the distribution of applicants by their particular fields of study. As can be seen, a a wide selection of disciplines were represented.

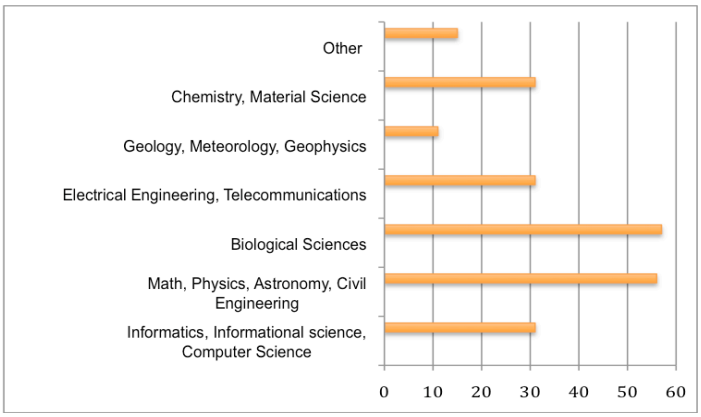

Fig. 2. The number of applications distributed by discipline.

We were pleased and intrigued by the great response, also considering the relatively strict timeframe from when the information about the workshop was announced in the beginning of January and until the registration deadline 1 February. That so many PhD students applied for the first offering of such a workshop is a testimony to the need for this type of education. The response is also particularly high since this workshop was a pilot—most students did not have any word from their peers yet as to its value. Moreover, the number of applications points to the gap that exists between what Norwegian PhD students are currently learning about these skills and what level the students believe that they should hold.

The workshop structure allowed a total of 68 participants. Of these places, 14 were reserved for the major sponsors, and 12 for PhD students at Simula. The remaining 42 places were open for the general applicants. In order to ensure the dynamics of the workshop, we aimed for making a selection based on spread of disciplines, spread of gender and nationality, and a geographical spread scaled according to the size of the university. More than half of the applicants and the final participants represented Norway's two largest institutions: the University of Oslo and the Norwegian University of Science and Technology in Trondheim. We also wanted to make sure that the participants were about half-way through in their PhD studies. First-year students are generally not far enough along in their research to be thinking about papers and presentations, and students about to finish their PhD are inclined to be less interested in experimenting with new communication skills and more focused on the completion.

Of the 68 participants for the national workshop, 56 slots ended up being held by PhD students and 12 by postdoctoral research scientists. Of those 68 participants, the selection process produced a distribution in which 28 were female (41%) and 40 were male (59%). In addition, those 68 participants represented 28 different countries and 25 different first languages. In summary, 30 participants were native Norwegians and the remaining 38 came from the 27 other countries represented in the workshop.

3.2 Level of commitment among the participants

The workshop was scheduled to take place in Oslo at 9 to 11 March 2009. The University of Oslo is by far the largest university in Norway with 35 000 students, and the capitol has direct train and flight connections with the other University cities in Norway. For this reason, it seemed natural to have the workshop in the Oslo area. The other universities in Norway are located in Tromsø, Trondheim, Bergen, Stavanger and Ås. The workshop funding allowed us to offer free food and lodging for the participants, but they needed to cover their own transport expenses. A three-day length of the workshop suited the workshop structure, both with reference to the teaching capacities and the budget. The length was also chosen with the participants in mind; it seemed reasonable that they would be able to travel and leave their place of work and spend three days focusing on improving their communication skills.

The workshop required a high level of commitment of the participants, both being three days away from their schedules and the preparation of several hours of workshop assignments. By having the participants prepare assignments beforehand and providing them with feedback on those assignments, we extended the learning window. For the national workshop, three such assignments were distributed: Three weeks before the workshop, all participants were asked to submit a set of presentation slides and an abstract from a recent talk. The gathered information was used to tune the contents of the lectures to specifically catch problems shared by several attendees, and to establish the baseline for later assessment of the teaching outcome. Two weeks before the workshop, the participants were asked to hand in an abstract and a set of slides for the presentation that the were planning for the workshop. In connection to this assignment, the participants received a compact introduction a new approach to slide design, including a tailored PowerPoint template. The participants were given individual feedback on basis of their submissions, often including the possibility of submitting revised documents. Finally, one week before the workshop, the participants were asked to submit a one-page summary of their research. This summary was later used for in-class exercises in the component Scientific Writing. Fig. 3 shows the timeline for the workshop preparations.

All communication between the instructors and the participants before the workshop started was based on a dedicated web platform hosted by Simula. This platform was a locally customized version of the Dokeos system [9], which is originally designed for e-learning. In total, more than 400 documents were submitted and commented upon over these three weeks.

As part of the component Scientific Presentations, the participants were split into groups of four members each. Three such groups and an experienced instructor made up one *critique session*. In each critique session, one group presented their research, one group asked questions as in a regular conference setting, and the members of the last group offered their individual critique of the four presentations in the session, as shown in Fig. 4. By cycling each group through the three roles of presenter, audience, and reviewer, each participant was involved in the discussion of 12 presentations. Each presentation, including the oral feedback to the presenter, was filmed, and the resulting video was made available exclusively to the presenter through downloading or streaming from the workshop's web platform. In this way, each participant was able to pick up the documentation of her own performance and the corresponding advice for private study.

Clearly, the organization of the critique sessions was the bottleneck with respect to the capacity of the chosen workshop format. With three experienced instructors each leading one of three parallel tracks of critique sessions, the maximum number of participants for the three-day schedule was 68. With access to more instructors and the necessary space and audiovisual equipment, a higher number of participants would be possible.

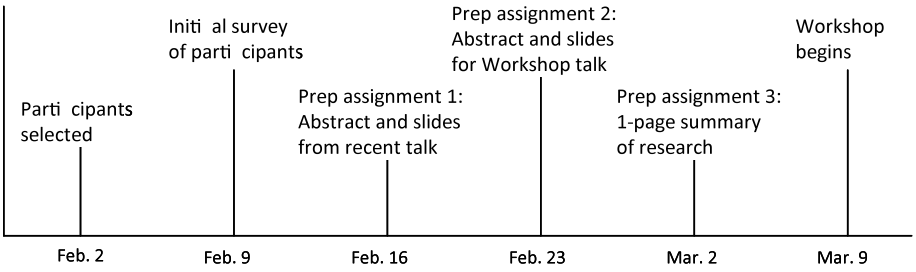

Fig. 3. Timeline for distribution of initial survey and preparation assignments. By having the participants prepare assignments beforehand and providing them with feedback on those assignments, we extended the learning window.

Fig. 4. A workshop participant presenting her research slides in the critique sessions. Group members are assigned specific roles as either reviewer of that session's presentations or audience members.

During the national workshop, each participant attended 11 hours of formal class, participated in a two-hour session in which he or she and three other participants presented their research and were critiqued, and attended two two-hour sessions in which the participant served as a reviewer or audience member for other presenting participants. Overall, the sessions were a learning experience that relied heavily on the engagement of the participants.

We were impressed by the commitment of the participating graduate students. Although the workshop was essentially free of charge for the PhD students (except for transportation to the workshop site), the workshop did require a dedication to both preparation and involvement in the group sessions. That so many applied and that the participants carried out the workshop with such a commitment and with such a short turnaround reveals that Norwegian PhD students are certainly interested and do feel a need to improve their research communication skills.

4 OBSERVED IMPROVEMENT OF PRESENTATION SKILLS

As an integral part of the national workshop, we collected data for the assessment of the A-E structure as a tool for design of presentation slides, as well as for the assessment of the learning outcome of the workshop. These data consist of three parts: (1) all submitted slides and abstracts, including baseline documents created before any instruction was given and all revisions of the documents

prepared through the assignments; (2) filmed presentations from the critique sessions, including the remarks made by the peers and the instructor; and (3) each participant's self-assessments collected through electronic surveys before and immediately after the workshop.

In this paper we report on the progress of five abilities according to the participants' own self-assessment. These measurements were performed before the participants received any instruction (pre-workshop) and immediately after the event (post-workshop). The five abilities in question are listed in the first column of Table 1. For each ability, the participants were asked to score their own level of confidence on an integer scale from 1 (no confidence) to 7 (much confidence). All 68 participants answered the pre-workshop survey, while 47 responded to the post-workshop survey. In the following discussion, we will denote the complete pre-workshop data set by *pre(68)* and the post-workshop data set by *post(47)*. The subcollection of pre-workshop observations that corresponds to the 47 individuals who responded to the post-workshop survey is referred to as *pre(47)*.

Table 1 shows the average scores for the five different abilities, using the data sets pre(68) and post(47). We can clearly see an increase in the average confidence scores for all abilities. Using paired t-tests to compare the mean differences for each ability, we conclude that the post-workshop average is significantly greater for all cases. In fact, all comparisons related to presentation skills are statistically significant at $p < 0.001$, whereas the comparison related to writing skills is significant at $p < 0.013$. This observation is consistent in the sense that considerably less workshop time was spent on writing than on presentation.

Table 1. Comparison of self-evaluations: pre-workshop versus post-workshop. The pre-workshop data was collected from all 68 participants, while 47 participants responded to the post-workshop survey.

Ability	Pre- (average)	Post- (average)	t	p
(a) To organize a research presentation	4.7	5.4	3.52	0.001
(b) To create slides for a research presentation	4.4	5.6	7.80	0.000
(c) To deliver a research presentation	4.3	5.4	6.70	0.000
(d) To present research to the public	4.2	5.4	6.32	0.000
(e) To write a research paper	4.5	4.9	2.57	0.013

Comparing the pre- and post-workshop results, one might wonder whether it is reasonable to use the complete (pre(68)) or the restricted (pre(47)) pre-workshop data sets. It seems possible that the population of 47 individuals who answered the post-workshop survey is dominated by those who found the workshop to be of most value. That is, the post-workshop results could be taken to be over-optimistic. Alternatively, one could assume that those with a low pre-workshop confidence in their own abilities did not see a point in making the necessary initial investment in learning the A-E structure for slide design, and that these individuals have not bothered to answer the post-workshop survey. However, if we compare the measurements in the data sets pre(68) and pre(47), the differences seem to be quite modest. Also, in those cases that imply some deviations, it mainly occurs for the mid-range scores 3-5. The corresponding difference between the two pre-workshop data sets is more or less symmetric with respect to the sign—see Fig. 5 – Fig. 9 .

For all cases depicted in Fig. 5 – Fig. 9, we see clear illustrations of the statistically significant improvement reported in Table 1. For the first four cases, all related to presentation skills, we see that the heights of the graphs corresponding to low to medium confidence scores (≤ 4) are reduced, and that the curves peak at the second highest score (6). In the last case, concerning writing skills, the trend is almost similar, although with a stronger clustering around mid-level scores (4 and 5).

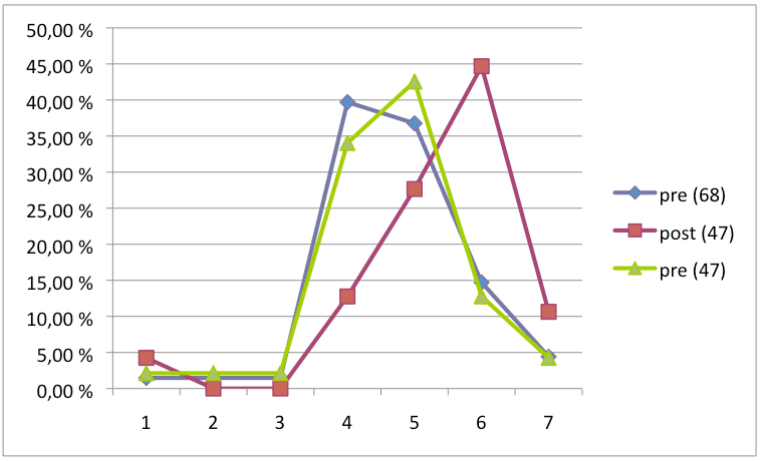

Fig. 5. Comparison of self-evaluations of the skill "(a) To organize a research presentation". The curve labeled pre(68) represents the pre-workshop answers from all 68 participants, while the two curves pre(47) and post(47) account for the pre- and post-workshop answers from the 47 individuals who responded to the post-workshop survey.

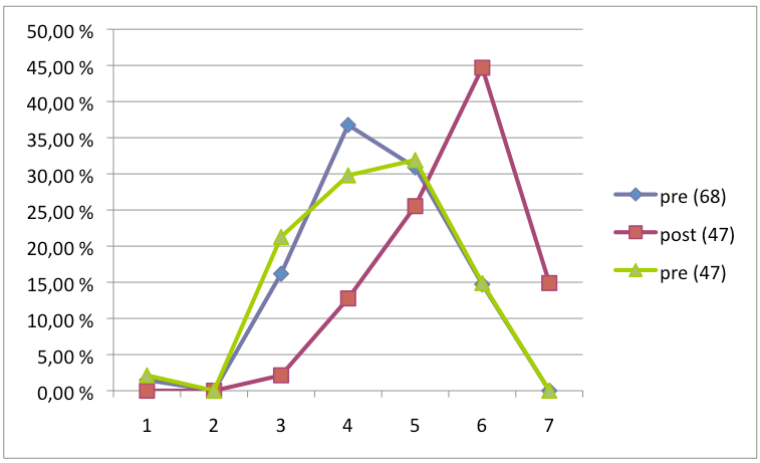

Fig. 6 Comparison of self-evaluations of the skill "(b) To create slides for a research presentation". The curve labeled pre(68) represents the pre-workshop answers from all 68 participants, while the two curves pre(47) and post(47) account for the pre- and post-workshop answers from the 47 individuals who responded to the post-workshop survey.

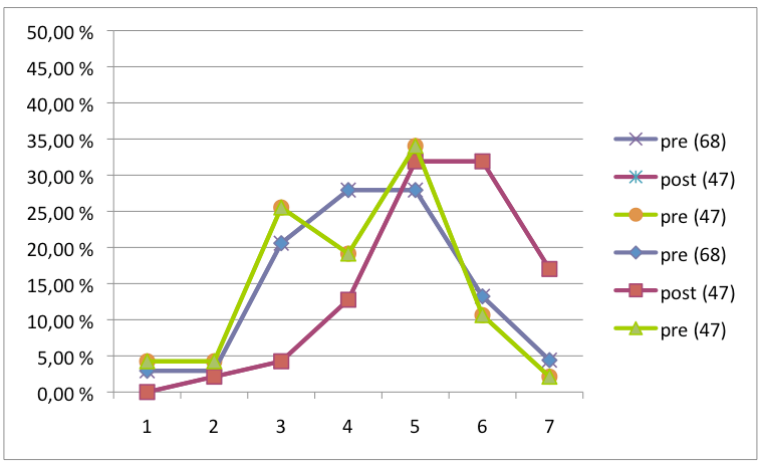

Fig. 7 Comparison of self-evaluations of the skill "(c) To deliver a research presentation". The curve labeled pre(68) represents the pre-workshop answers from all 68 participants, while the two curves pre(47) and post(47) account for the pre- and post-workshop answers from the 47 individuals who responded to the post-workshop survey.

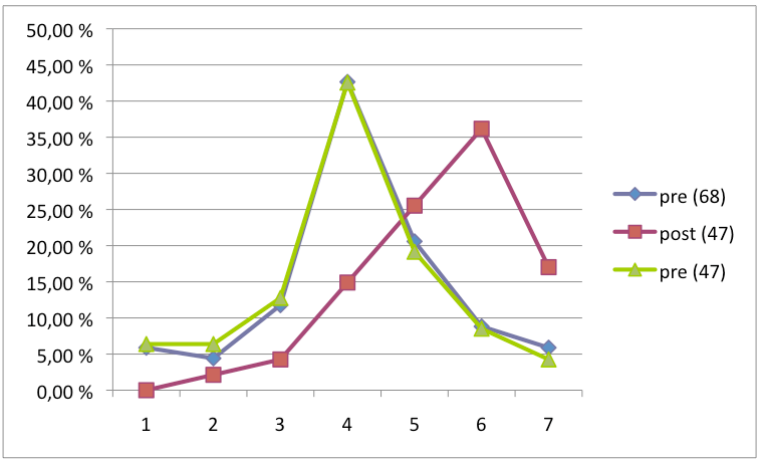

Fig. 8. Comparison of self-evaluations of the skill "(d) To present research to the public" The curve labeled pre(68) represents the pre-workshop answers from all 68 participants, while the two curves pre(47) and post(47) account for the pre- and post-workshop answers from the 47 individuals who responded to the post-workshop survey.

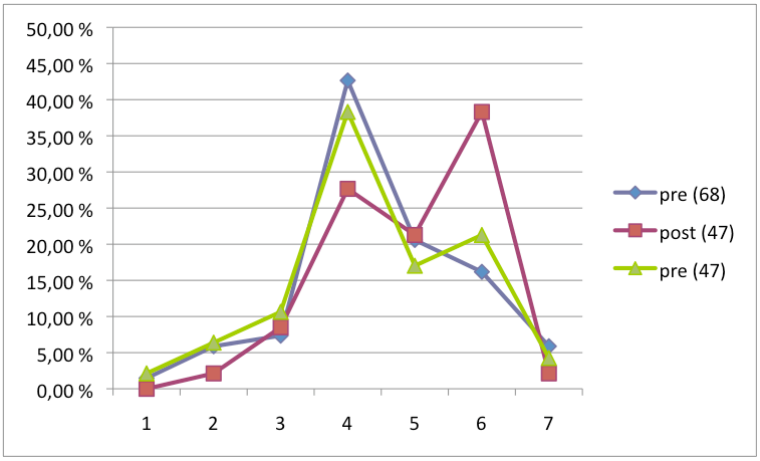

Fig. 9. Comparison of self-evaluations of the skill "e) To write a research paper". The curve labeled pre(68) represents the pre-workshop answers from all 68 participants, while the two curves pre(47) and post(47) account for the pre- and post-workshop answers from the 47 individuals who responded to the post-workshop survey.

To further explore the effect of the training, we have looked the percentages that report high scores. For this purpose, we used the data sets pre(68) and post(47), for which we have counted the occurrences of scores ≥ 5 and ≥ 6. The results are displayed in Table 2.

Concentrating on the abilities (b), (c) and (d), all related to designing and delivering a presentation, we see that the share of participants who report a confidence level at 5 or larger typically raises from 45% or lower to more than 80%. For case (a), the ability to organize a research presentation, we also see a strong improvement, although to a lesser degree than for the other presentation-related abilities. The effect concerning ability (e), to write a research paper, is less. This observation is as expected, since the component Scientific Writing did not contain any critique sessions. Also, experience shows that the intensive workshop format is less suited for the component on writing than for the components on presentation.

Still focusing on presentation skills and turning our attention to the very highest scores, 6 or 7, we see that the corresponding shares of participants systematically raise from the range 15%-19% to levels between 50% and 60%. We also observe a postive development concerning writing skills, for which the share goes from 22% to 40%.

Table 2. Comparison of self-evaluations: pre-workshop versus post-workshop. The numbers refer to the percentages of the respondents who marked the three and two highest scores, respectively. The pre-workshop data was collected from all 68 participants, while 47 participants responded to the post-workshop survey.

Ability	Score ≥ 5		Score ≥ 6	
	Pre-	Post-	Pre-	Post-
(a) To organize a research presentation	55.9%	83.0%	19.1%	55.3%
(b) To create slides for a research presentation	45.6%	85.1%	14.7%	59.6%
(c) To deliver a research presentation	45.6%	80.9%	17.7%	48.9%
(d) To present research to the public	35.3%	78.7%	14.7%	53.2%
(e) To write a research paper	42.7%	61.7%	22.1%	40.4%

5 CONCLUSIONS

We have described the design and implementation of a national workshop aimed at teaching Norwegian PhD students and postdocs effective techniques for scientific presentation and writing. In section 1 we posed three questions concerning the implementation and outcome of the workshop. These questions have been answered positively: (1) we have demonstrated that communication skills can be taught in a workshop style to a large number of students, 68; (2) a large number of Norwegian graduate students, 232, applied for a seat in the workshop despite the substantial investment of time and energy required from the participants; and (3) the self-assessments provided by the participants prove that the workshop has led to significant improvement in communication skills for most of them.

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