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Clarity of Scientific Presentation: Prerequisite for the Communication Between Scientist and the Public

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SUMMARY

Based on our editorial, scientific, and educational experience, we think that most problems in communication between scientists and the general public could be avoided if scientists underwent training in communication skills early in their careers. Unfortunately, such training is ignored by most university curricula. Scientists are primarily trained to become dexterous in the technical aspects of science, whereas the acquisition of communication skills is almost completely overlooked, despite the fact that communication and clear presentation of research results is a constituent part of scientific work. Above all, scientists are evaluated according the number and quality of their scientific publications, which largely depends on their skill in presenting their research data to their colleagues in a clear and comprehensible way. We present the theoretical framework for understanding the confounding factors that hamper communication among scientists and between scientists and the general public. Poor or non-existent systematic teaching of scientific methodology, low academic criteria, and low quality of the journals are the main confounding factors affecting scientific communication in a small scientific and academic community. We describe the example of the Croatian Medical Journal *(CMJ), which while struggling (successfully) to become an internationally recognized journal made an effort to teach its authors the principles of scientific communication and to institute an author-helpful policy of manuscript review. This experience helped us realize that the writing/communication skills should be*

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taught as early as possible, i.e., to undergraduate students – future medical researchers. With the support of the Zagreb University School of Medicine, we introduced a compulsory undergraduate course in scientific research in medicine, while the second-year students are taught the principles and ethics of scientific research, access to literature and citation databases, critical reading of scientific articles, and application of medical statistics in practice. In addition, they are taught about the principles of scientific writing and the importance of clarity and simplicity in presenting scientific research.

Key words: communication skills, scientific communication, education of the authors, principles of communication in science, writing of scientific paper, scientific work in biomedicine

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The man of science appears to be the only man who has something to say just now, and the only man who does not know how to say it.

Sir James Barrie
(1860-1937)

As the above citation reveals, the problem of communication between scientists and the public is not new. Why do scientists have problems in communicating their research to the public, or why does the public so poorly understand science and the scientists? The misunderstanding comes as a surprise, having in mind the fact that communication lies in the very core of scientific work. Scientists constantly exchange information, mostly in the form of scientific publications. Actually, publication is the final phase and the goal of every scientific research, the best way to present a scientific discovery to scientific community. A scientist is measured by his or her publications, rather than dexterity, hours spent in the laboratory, or knowledge on the subject. Scientist must produce a written document explaining why the research was done, how it was done, what was found, and what the findings meant. Knowledge, which is the possession of the whole humanity, is increased, accumulated, and integrated through a communication system based on published scientific work. Thus, scientific publication is not only a result of the scientific research, but also new information for the mankind.

Making the results of research publicly available does not only imply that a scientist has to write a report on his/her work, but also that he/she has to write it understandably to other scientists or intended readership. Only thus can new scientific knowledge be recognized and added to the existing body of global

scientific knowledge. This means that a scientific experiment is not complete until the results have been published *and* understood. Therefore, the major characteristics of scientific communication are simplicity, precision, and clarity. Scientific language differs from everyday language or language of fiction. Flowery literary style, metaphors, and idiomatic expression will cause confusion and thus cannot be used to communicate science.

Sources of misunderstanding between scientists and the public

If we accept the above as sound and logical, then why is there a constant misunderstanding between the public and scientists? We believe that the origin of this problem stems from the poor quality of communication among scientists themselves. The sad fact is that most scientists do not like to write papers and many good scientists are poor writers. Charles Darwin said, "A naturalist's life would be a happy one if he had only to observe and never to write" (Day 1988). Why is it so? The answer is in the education of scientists. In most curricula, teaching of communication skills is neglected or ignored. This is true not only for small scientific communities from the so-called "scientific periphery", such as Croatia, but also for the majority of academic communities producing the "mainstream science". There are many excellent books on principles of scientific writings (Day 1988; Byrne 1997; Huth 1999; O'Connor and Woodford 1975), but few people read them. Students are busy learning from the prescribed textbooks and nobody teaches them the responsibility of communicating the results of their work. When they become graduate students, they mostly imitate the style of their mentors and/or articles they have read in scientific journals. Scientists who should teach them had no formal education in scientific writing. Since they had a similar apprenticeship in another laboratory or clinic, they usually neglect the fact that science should be "communicated" as well as "done".

Vicious circle of inadequate communication skills in science

In our previous articles we analyzed the problems facing a small journal in a small scientific community and defined ways of getting out of the scientific periphery into the mainstream science (Marušić A & Marušić M 1999; Marušić M & Marušić A 2001). In this article we propose a theoretical framework for the analysis of the confounding factors of poor communication among the biomedical scientists and between them and the public. This we did from the point of view of a small country with a small scientific community. Confounding factors associated with poor communication skills can be identified

at every level of education and professional life of a scientist, leading into a vicious circle of inadequacy which constantly aggravates the situation (Figure 1). Firstly, and maybe most importantly, there are almost no undergraduate courses in scientific method and writing. If there are, they are elective rather than mandatory. Making them mandatory would be the only way to ensure that the education covers the whole targeted population (i.e., students in different scientific fields). Graduate education, on the other hand, offers short and rather easy-going courses in scientific methodology, which students do not take very seriously. Also, only a relatively small number of people take such courses. Furthermore, the criteria for academic advancement are generally low and do not provide sufficient incentive for improving the knowledge in scientific method and writing. Medical schools do not provide this type of education at all: the system of continuing education is still in the process of development and the awareness of the need for knowledge on scientific method is almost non-existent.

Scientists cannot get the idea of what a scientific report and communication in science should look like by reading local "scientific" journals either, because domestic journals mostly publish articles of low quality (Mišak et al 2002). Incomplete education leads to insufficient knowledge on scientific methodology and lack of research and communication skills (important in everyday medical practice!), and thus the vicious circle of inadequacy closes (Marušić A & Marušić M 1999). This kind of ignorance may often lead to more serious consequences, such as medical irrationality (e.g., turning to paramedicine) and even fraudulent practice. The final result is the lack of clear and simple communication between scientists on one side and the general public and patients on the other.

Teaching scientific method and writing to physicians: experience of the *Croatian Medical Journal*

We have seriously approached this communication problem at the Zagreb University School of Medicine. Fifty years of an egalitarian system of financing scientific research, which produced little main-stream science, have left Croatian scientists without the skills needed for publishing scientific articles in international journals (Lacković 1992). In 1992 we started a new journal, the *Croatian Medical Journal* (CMJ), a quarterly (now a bimonthly) publication in English, open to all types of contributions from all fields of biomedicine. CMJ had four basic goals (Marušić A & Marušić M 1995/96): 1) to set the quality standards for scientific reporting; 2) to assist domestic authors in scientific writing and help them improve their writing skills; 3) to establish communica-

tion with Croatian biomedical experts working abroad, and connect them with the national researchers; and 4) to present Croatian medical science to the international scientific community. Our experience with CMJ contributors, especially contributors to CMJ War Supplements, revealed that the greatest weaknesses of Croatian physicians were their unwillingness to write in a proper scientific style and their fear of obstacles waiting along the publishing process. So the CMJ Editorial Board settled down to work with authors and help them improve the presentation of their data (Marušić A 1998).

Work with CMJ Authors

We have introduced an "author-friendly" pre-review of manuscripts submitted to the CMJ by domestic authors. The aim of pre-review is not only to improve data presentation but also to educate authors on scientific writing (Marušić M & Marušić A 2001). The pre-review process starts with the editor-in-chief, who reads the manuscript and, if the data are sound, returns the manuscript to the author with detailed instructions on how to improve their presentation. The manuscript can be "exchanged" several times before the appointed Editor and the Statistical Editor become satisfied with the presentation of data. The manuscript is then sent out for international peer-review. If the reviews are commendable, the author is asked to make the requested changes and send the revised version to the Editor. The final version goes through the hands of the Manuscript Editor with a BA degree in English, who does language editing. The editor-in-chief makes a final check for any remaining flaws. In this way, we saved a lot of valuable data from being lost to the scientific community for the reasons of poor presentation (Marušić A & Marušić M 1995/96). Over the years, *CMJ* became a key-source of scientific data on the medical aspects of the wars in Croatia and Bosnia and Herzegovina (Horton 1999:2139; 1999:2223).

Work with Authors Writing for Other International Journals

To help them break out from the isolation of the "scientific periphery", we have encouraged physicians with experience in war medicine to present their work to the international medical community (Marušić A et al 2002). We used a similar approach with CMJ authors (who mostly already had that experience); during the process, the authors learned more about secondary publications, journal indexing, and styles used in different journals. Our joint efforts over the last ten years resulted in more than a hundred articles published in non-Croatian journals indexed in Index Medicus, Current Contents, and Science Citation Index, and 150 in the CMJ (Marušić A & Marušić M 1995/96).

Work with Future Authors – Medical Students

Extending their educational activities to working with students was a natural move for the CMJ Editorial Board. With the help and support of the Zagreb University School of Medicine, four members of the Editorial Board introduced a mandatory undergraduate course in scientific research into the curriculum, starting with the 1995/1996 academic year. Our aim was to teach second-year students the principles and ethics of scientific research, access to literature and citation databases, practical approach to medical statistics, and principles of scientific writing. We wrote a textbook in Croatian (Marušić M et al 2000) that covered the basic aspects of scientific research, information and communication in medicine, and scientific writing (Table 1). We also translated the book of essays on medicine by Lewis Thomas, "The Youngest Science. Notes of a Medicine Watcher" (Thomas 1955), and offered it to students as additional reading. Thomas' book gives the students an insight into how medical research was done in the past and how medicine progressed into a high-technology science as it is today. During the course, students become familiar with the structure of a scientific article and the basic rules of scientific writing. The exercises are mainly directed towards structuring an abstract from a journal article without a structured abstract. The students are also encouraged to write an abstract from a text prepared from various articles covering topics familiar to them. This helps the students get acquainted with the type of clarity and simplicity required in the presentation of scientific research. Most medical students have sound knowledge of English but the course does not aim to teach them stylistic subtleties of the scientific English – it teaches basic prerequisites for scientific research, common to all languages: thinking about the requirements of the scientific proof, logical development of the scientific argument, and precision of the scientific expression.

We have decided to work with second-year medical students because we wanted them to use that knowledge in the future and be able to critically appraise and evaluate the literature they have to read and study from, especially for clinical courses. We also hoped that the course would give them new ideas about their own research and encourage them to enter the research in the field of their choice without fear. Students with better scores on the admission exam and first-year exams usually hold more positive opinion on the course and show higher motivation to learn about scientific method (Vodopivec et al 2002).

The course we described is one of the possible methods of teaching scientific method. We welcome all criticism and suggestions from students, teachers, and scientists.

The benefits of our investment into education of physicians and students paid back: the number of high-quality scientific articles submitted to CMJ for publication has been constantly increasing, as well as the number of authors who want to present Croatian medicine to the international scientific community (Mišak 2001) (Figure 2). We hope that the academic community and, eventually, the public in general will benefit from our work (Figure 2). Our main objective – making the academic community aware that the teaching of principles of scientific research and scientific writing is an essential element in the training of every scientist – has been attained: all other medical schools at universities in Croatia have introduced similar courses in their curricula. We strongly believe that investing into education of Croatian students – future researchers and those who will determine the future of Croatian science – will prove worthwhile and lead to the improvement in quality of scientific research in Croatia (Huth 1998).

Suggestions for the Future

We believe that poor communication skills of scientists are the most important reason of poor communication of science to public. This setback has its root in the lack of formal training in scientific writing and scientific method. Scientists have considerable troubles in communicating (writing and presenting) their own data or expertise among themselves, i.e., to scientific journals. Science editors experience and struggle with this problem in their everyday work. However, further communication of science – not to experts who use jargon, who are trained to think analytically, and who are used to succinct and difficult information, but to the public, who needs information in a totally comprehensible form poses an even greater problem. However, instead of educating scientists to communicate scientific information to the lay public, or media reporters to understand scientific methods, scientific thinking and jargon, we believe that the first and earliest step is to train scientists to communicate clearly and simply their data to fellow scientists. Therefore, we advocate introducing a course on scientific method and writing into mandatory university training. This applies not only to biomedical sciences, but also to other scientific fields.

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Table 1. Topics taught in the course on the scientific method and writing for second-year students of the Zagreb University School of Medicine*

PART I: Scientific thinking

1. Science
   - 1.1 Science as a value system (Cultural role of science, Science as a school of honesty and moderateness, Science as a source of cognition, Science as a source of security and progress)
   - 1.2. Basic characteristics of science (Science and nature, Science and truth)
   - 1.3. Recognition of science (Question of dialogue, Question of choice, Choice of science)
   - 1.4. Medicine is science (Scientific nature of medicine, Scientific research in medicine)
2. Scientific thought
   - 2.1. Cognitive basis of the scientific thought (Man and truth: sources of error, Belief, Rational and irrational beliefs)
   - 2.2. Sources of the scientific thought (Drive for investigation, Originality, Science and poetry)
3. Scientific method
   - 3.1. Logic in scientific research (Experiment design, Interpretation of results, Scientific progress)
   - 3.2. Hypothesis (Scientific hypothesis as a basic scientific method; Value measures of scientific hypothesis)
   - 3.3. Results
   - 3.4. Evidence
   - 3.5. Publication
   - 3.6. Ethics of scientific research (Ethics of scientific community, Work ethics, Ethics of publishing research)
4. Paramedicine and its fallacies
   - 4.1. Survey of paramedical activities (Traditional folk medicine, New medicines, Special diets, Bioenergy and parapsychology)

* Titles of chapters in the textbook written for the course (14).

4.2. Sources of interest for paramedicine (Critique of modern medicine, Successes of paramedicine)
4.3. Paramedicine and medical education
4.5. Paramedicine and medical professionals

PART II: Scientific research

1. Basis of scientific research
   1.1. Types of research
   1.2. Planning of research
   1.3. Experiment (Clinical experiment)
2. Statistical foundations of scientific research
   2.1. Research logic (Probability models, Population and sample)
   2.2. Hypothesis (Scientific hypothesis, Statistical hypothesis, Argumentation of a hypothesis)
3. Measurements in medicine
   3.1. Measurement scales (Nominal scale, Ordinal scale, Major scales)
   3.2. Accuracy of data (Error of data, Reliability of measurement, Reliability of performance)
4. Analysis and representation of data
   4.1. Collection of data (Sources of data, Simple and complex data)
   4.2. Analysis of data (Data storage, Conversion of data)
   4.3. Representation of data (Tables, Illustrations)
   4.4. Interpretation of data

PART III: Scientific information

1. Communication of new medical information
   1.1. Formal and informal ways of communicating information
   1.2. Printed and electronic information media
2. Sources of medical information
   2.1. Characteristics of medical literature
   2.2. Systematization of medical literature (Primary publication, Indexing languages, classifications, and thesaurus; Secondary publications; Tertiary publications)
   2.3. Bibliographical databases
3. Informational needs and information search
   3.1. Practicing medicine requires information (Scientific research, Education, Writing scientific reports; Solving clinical problems)
   3.2. Strategy of searching form information
   3.3. Access to printed indexing publication
   3.4. Access to bibliographical databases (On-line, CD-ROM)

3.5. Finding original documents (Library, Reprint requests)
3.6. Archiving information for personal needs
4. Literature references
4.1. Basic rules
4.2. Basic systems (Alphabetical system; Numerical system; Alphabetical-numerical system; Vancouver system)

PART IV: Scientific paper
1. Presenting results of scientific research
1.1. Argument in logic and structure of the scientific paper
1.2. Articles in scientific journals (Original scientific paper, Case report, Review, Book review, Letter to Editor)
1.3. Other types of communicating research (Thesis, Oral presentation, Poster, Research grant, Curriculum vitae)
2. Before writing scientific paper
2.1. Six questions about the paper (What do I want to say?, Should I write the paper?, Did I publish something similar?, What type of paper should I choose?, Who is the audience?, Which is the right journal?)
2.2. Preparation of data and literature
2.3. Preparation for writing
3. Original scientific paper
3.1. Structure (Title, Abstract, Key words, Introduction, Methods, Results, Discussion, References, Tables and illustrations)
3.2. Writing a scientific paper (Style, Rewriting and editing)
4. Publishing paper in a journal
4.1. Sending manuscript to a journal
4.2. Decision of journal editor (Peer-review, Galley-proofs, Reprints)

Figure 1. The vicious circle of inadequate teaching of physicians in scientific method and writing: consequences for their practice and communication with the public. The vicious circle means that insufficient knowledge, lack of skills, medical (scientific) irrationality, and fraudulent practice actually *increase* in time. This academic inadequacy mediates low quality work and faulty knowledge through local journals of low quality and low publishing criteria (Marušić A & Marušić M 1999; Marušić M & Marušić A 2001). Low quality work and faulty knowledge result in an anti-scientific avenue of education and negative attitude of practicing physicians to science (e.g., evidence-based medicine). In academic circles these factors maintain low criteria and suppress incentive for advancement; they devaluate postgraduate education and thus enhance wasting

the chance to produce top-level intellectuals; and remove scientific approach and method from graduate education, which results in the lack of minimum knowledge in graduates.

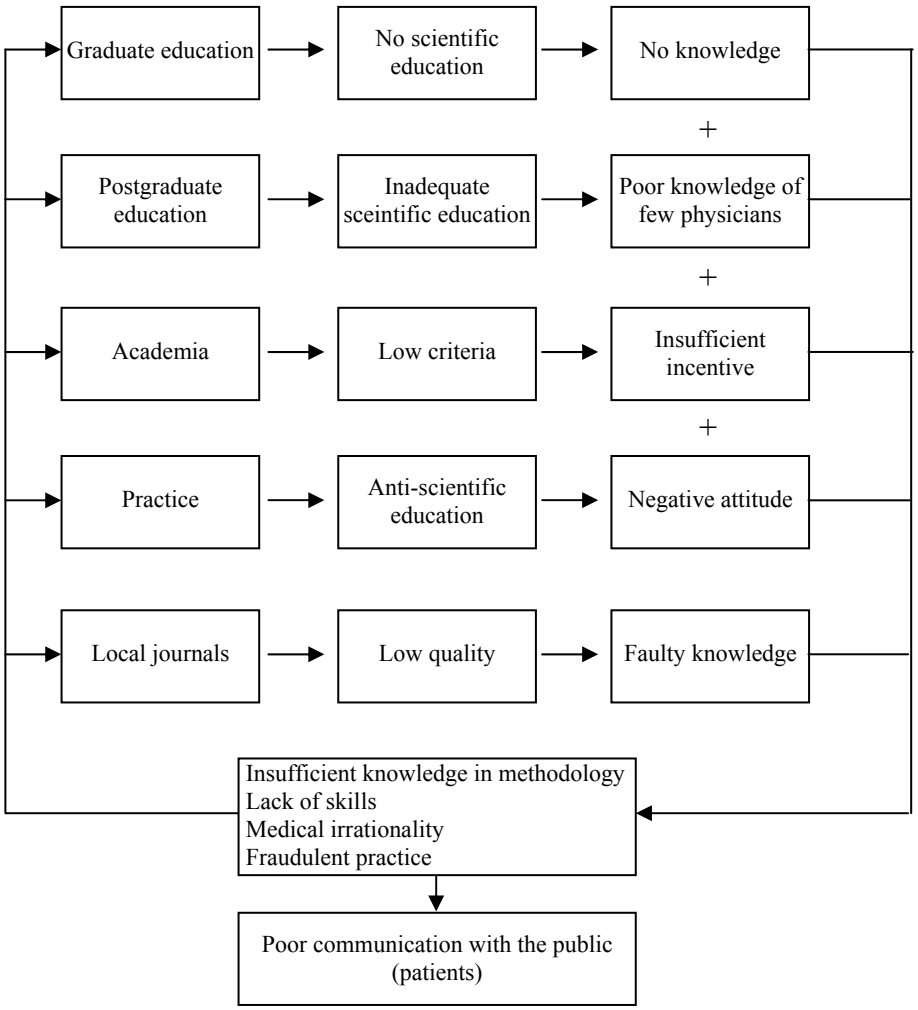
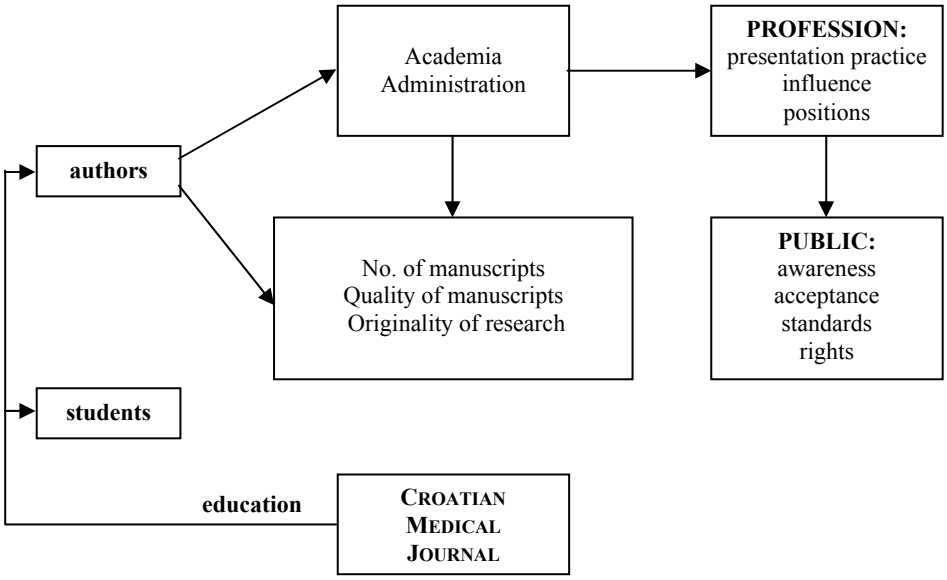


Figure 2. Benefits of teaching physicians the principles of scientific method and writing. The *Croatian Medical Journal* (*CMJ*) started intensive education of its potential authors (1991) and medical students at the Zagreb University School of Medicine (1996). The authors, with increased awareness on the importance of scientific publishing, and improved research planning and reporting skills paid back with increased number of better quality manuscripts submitted for the publication in the *CMJ*. They also positively influence their academic, professional and administrative circles, which results in better performance and higher criteria of professional practice, presentation of data and problems, more objective human resources management, and professional interactions. This, in turn, improves public awareness and acceptance of science, standard of expectations from the medical profession, and awareness of patient rights. As the action of the negative, confounding factors forms the vicious circle of inadequacy (see Figure 1), a single positive effect produces an avalanche of effects which improve the general communication level and quality of life. The scheme described in this Figure is a theoretical model, which is based on our qualitative data. Quantitative analysis of the benefits produced by teaching journal authors and medical students principles of scientific communication is currently underway at the Zagreb University School of Medicine.



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Jasnoća znanstvenog izražavanja: Preduvjet za komunikaciju između znanosti i javnosti

SAŽETAK

Na osnovi vlastitoga uredničkog, znanstvenoistraživačkog i nastavničkog iskustva, mislimo da bi se problemi u komunikaciji između znanstvenika i javnosti velikim dijelom mogli izbjeći ako bi znanstvenici već na početku svoje karijere stekli određene komunikacijske vještine. Nažalost, većina nastavnih programa visokoškolskih ustanova zanemaruje taj dio obrazovanja znanstvenika. Znanstvenike se prije svega obrazuje u tehničkim aspektima znanosti, dok se stjecanje komunikacijskih vještina zanemaruje, iako su komunikacija i jasno prikazivanje rezultata istraživanja sastavni dio istraživačnoga rada. Uspješnost znanstvenika mjeri se ponajprije brojem i vrsnoćom objavljenih znanstvenih članaka. U ovom radu obrazlažemo kako određeni čimbenici otežavaju komunikaciju kako između samih znanstvenika, tako i između znanstvneika i javnosti. Nedostatak ili nepostojanje sustavnog podučavanja znanstvene metodologije, niski akademski kriteriji i niska kakvoća znanstvenih časopisa glavni su čimbenici koji negativno utječu na znanstveničku komunikaciju u maloj akademskoj zajednici. Kao primjer kako se može utjecati na poboljšanje komunikacijskih vještina znanstvenika navodimo rad časopisa Croatian Medical Journal (CMJ). Dok smo marljivo radili na tome da CMJ postane priznat međunarodni znanstveni časopis, istodobno smo obrazovali naše autore i poučavali ih načelima znanstvene komunikacije, pa smo u sklopu toga uveli i postupak prerecenzije znanstvenih članaka. To nas je iskustvo dovelo do zaključka da bi autorima trebalo omogućiti da vještinu pisanja i komuniciranja steknu na samom početku svoje karijere. Tako smo, uz podršku Medicinskog fakulteta Sveučilišta u Zagrebu, uveli "Uvod u znanstveni rad u medicini" kao obvezan predmet za studente druge godine medicine. Tijekom "Uvoda" studente se podučava načelima i etici znanstvenog istraživanja, pretraživanju literature i baza podataka, kritičkom čitanju znanstvneih članaka i primjeni medicinske statistike u praksi. Osim toga, studenti se upoznaju s načelima pisanja znanstvenog rada i znanstvenim stilom, čije su najvažnije osobine jasnoća i jednostavnost izražavanja.

Ključne riječi: komunikacijske vještine, znanstvenoistraživački rad, obrazovanje autora, načela znanstvene komunikacije, pisanje znanstvenog rada, znanstveni rad u medicini