

The Impact of a Planned Strategy of Early Scientific Research Training on Medical Students' Research Productivity

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ABSTRACT

Student Research and Innovation Program (SRIP) is one of the major training programmes and is broadly used to promote students' ability of scientific research. However, the exact impact of a planned strategy of early SRIP on the research productivity of medical students remains unknown. Here we conducted a complete and reliable questionnaire survey to investigate the situation of early SRIP in improving the research interests and the academic index was used to evaluate the research productivity in medical students. The results showed that more than half of medical students at Ningbo University School of Medicine participated in SRIPs in junior grades. Personal interest was a major motive and selective criteria for SRIP. Meanwhile, SRIP was found to be self-managed and well arranged in medical students. Interestingly, early scientific research training benefited students in both academic and non-academic achievements. The statistical analysis showed that the freshman participants yielded the most productive academic achievements. Additionally, the planned SRIP is considered useful, challengeable, and supportive for medical students. These findings reveal the potential value of the wider implementation of early SRIP throughout the school years in enhancing the research ability of medical students.

Keywords: Medical Education, Research Productivity, Scientific Research, Student Research Innovation Program, Undergraduate

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I. INTRODUCTION

The 5-year-program of undergraduate clinical medicine is the mainstream of post-high school medical education in China. The State Council of China issued a plan to reform medical education and promote collaboration between medical education and practice in 2017. A "5+3" training system, a 5-year-program of undergraduate clinical medicine plus a 3-year resident training or a 3-year postgraduate program, will be generally set up (Song *et al.*, 2017; The, 2017). In the meantime, more qualified medical professionals with knowledge, skills and clinical thinking ability, should be trained to improve the public healthcare service. Thus, both basic research and clinical training programmes play critical roles in the development of clinical skills and clinical thinking ability (Cepanec *et al.*, 2016; de Oliveira *et al.*, 2011; Elharram *et al.*, 2017).

Although most of the new progresses in clinical medicine are developed by clinicians, there is an alarm about a decline in the number of clinician scientists. The proposed solutions have focused on resident physicians and junior faculties. During the clinical period, different training programs are

involved in clinician scientist education (DeLuca *et al.*, 2016; Luft, 2016; Mark & Kelch, 2001). However, to bridge the gap in knowledge between scientists and clinicians, it is urgent to connect basic research and translational medicine at the college education stage (Niessen & Krieg, 2014). Student research and innovation program (SRIP) is one of the major training programmes and is broadly used to enhance the research ability (Dicianno *et al.*, 2016; Fang & Meyer, 2003; Li *et al.*, 2018). In detail, the SRIP at Ningbo University School of Medicine is usually to carried out in the following steps: (1) Collect research topics from the college-wide faculties and students; (2) Determine the research contents and objectives in the formal proposals; (3) Screen the SRIP candidates by competitive evaluation of proposals; (4) Approve the SRIPs by the academic committee of the university; (5) Finish the SRIPs within the project schedule following the guidance of the faculties; (6) Measure the performance of SRIPs by academic and non-academic achievements. SRIP was originally developed as part of their core curriculum to instill students' skills and motivations including research and innovation. It is reconstructing the educator-student relationship and promoting research education among undergraduate students (Galeano *et al.*,

2012). Since we began the SRIP in 2007, different outcomes of SRIP have been achieved, such as technical developments, academic publications, inventions and patents, clinical applications, and an increase in the training of clinicians (Bevitt, 2015; Wolkow *et al.*, 2014). As one of the central strategies that promotes the research ability among medical students, SRIP has been implemented for 11 years at Ningbo University School of Medicine. However, the exact effect of a planned strategy of early scientific research training on the research ability of medical students remains unknown.

Here we conducted a complete and reliable questionnaire survey to investigate the situation and to reveal the impact of early SRIP on medical students' research ability and the scientific innovation level. Thus, this study would provide a novel insight into the role of early scientific research training in research ability of medical students.

II. METHODS

A. Questionnaire Design and Data Collection

To assess the basic situation, arrangement quality and the impact of SRIP in education, the questionnaire was designed with different parts: (1) the basic situation of participating in SRIP, (2) the motives and requirements for scientific research, (3) the arrangement of SRIP, (4) the students' achievements from SRIP, (5) the students' experience from SRIP, (6) overall assessment of SRIP, and (7) other subjective assessments and suggestions for scientific research. All of the different questions covering the above seven parts were set on a single survey paper. The questionnaire was constructed and validated for the research purpose. The questions were evaluated by the committee of undergraduate research work. The questionnaire survey was proved by Medical Research Ethics Committee of Ningbo University School of Medicine (IRB No. NBU-2019-011) and conducted at Ningbo University School of Medicine. The students of each year from Freshman Year to Senior Year were randomly required to answer the questions on the paper. Then the papers were collected, and the original data was converted into an Excel document. The completeness, accuracy and consistency of the collected data were confirmed by three different independent investigators.

B. Survey on the Basic Situation of Participating in SRIP

Students were required to answer the basic information of scientific research as follows: (1) gender, (2) have or do not have experience of participating in SRIP, (3) supervised by whom, (4) first time involved in scientific research, (5) total time spent in research, (6) hardware and cultural environment in research lab. Then the collected data was analysed to evaluate the current situation of participating in scientific research.

C. Survey on Motives and Requirements for Scientific Research

Since the SRIP is a voluntary participation program for all medical students, the motives for scientific research were surveyed, including personal interest, creative credit, scholarship, award, and being a medical scientist, etc. For the supervisor selection criteria, interest of research field, personality of supervisor, previous achievements and high

academic standards were set for students to choose the most suitable option. In addition, the goals for participating in research and the source of SRIP were evaluated by the results of selection.

D. Evaluation of the Arrangement Quality of SRIP

To evaluate the arrangement of the SRIP, we evaluated the time arrangement, guidance frequency, active report frequency for students who participated in scientific research. Students were asked to reply whether they had finished a complete research project. Since SRIP is a team work, students were also required to response to their understanding of the collaborator's work.

E. Evaluation of the Impact of SRIP on Research Productivity

First, the students were required to show their greatest benefit from the scientific research. Then both of academic and non-academic achievements were used to evaluate the impact of participating in SRIP in research ability. For academic achievements, the publications such as academic papers, patents and awards were set. The students were divided into three groups: (i) the students who participated in SRIP from the freshman year ($n=58$), (ii) students who participated in SRIP from the sophomore year ($n=17$) and (iii) students who participated in SRIP from the junior year ($n=3$). To evaluate the impact of SRIP, we introduced a new concept of "Academic Index (AI)". At the end of the fifth year, the academic achievements were collected. In each of the above group, the total number of academic achievements was set as a direct AF (DAI). Then, the average value of the number of academic achievements divided by the sum of participants was set as an average AI (AAI). Finally, the value of AAI divided by the sum of participants' time (year) was set as a relative AI (RAI). The impact of SRIP on research productivity was ranked by the RAI value. Meanwhile the primary factors in academic achievements were analyzed by the efforts of students, supervisors, and/or both of them.

F. Analysis of Students' Experience from SRIP

The usefulness of scientific training (including skills, safety and standards) was evaluated as useful, insufficient or useless level. During conducting SRIP, students described the pressure of scientific research from their supervisors or themselves. Moreover, the contributions of SRIPs to the supervisors' lab were also required to response to. For better experience, students shared the anticipation of scientific research during the undergraduate period.

G. Overall assessment of SRIP

For the assessment of research project, students were required to evaluate the level of the research as difficult and challengeable, easy and challenging, easy and confident, very easy and not sure. For the quality of supervision, the subjective assessments were set as different levels, such as excellent, very good, good, bad, and not sure, for students to choose. Also, students were required to use one positive and one negative word to describe the research experience. Some kinds of efforts that should be put into the undergraduate scientific research were suggested by students.

H. Statistical Analysis

The data analyses were performed using SPSS 13.0 software.

III. RESULTS

A. More than Half of Medical Students Participate in SRIPs in the Junior Grades

To investigate the current situation of participating in SRIPs, the basic information of medical students participating in scientific research was collected and analyzed. One hundred and forty-five students were eligible to be surveyed and 139 effective questionnaires were collected with a 96% response rate. Among the surveyed students, 63% of them are female and 37% of them are male (Fig. 1A). Fifty-six percent of the students have the experience of scientific research, while 44% of the students do not have the experience (Fig. 1B). Most of the students (96.1%) were supervised by faculty members in medical school, only a very small portion of students were supervised by faculty members in other schools (Fig. 1C). For the first time involved in scientific research, 75.6% of the students started their SRIP from the freshman year and 21.8% of the students started from the sophomore year. Only 2.6% of the students did their research work from the junior year (Fig. 1D). The total time for participating in research ranged from one month to over two years. Forty one percent of students spent one to two semesters (0.5-1 year) in scientific research. Almost one fifth of the students performed research work for less than one semester or two to three semesters (1-1.5 year). Only few students (7.7%) did more than two-year research work (Fig. 1E). In addition, almost half of the students (42.3%) assumed the hardware environment is good or above (Fig. 1F), and more than half of the students (68.0%) assumed the cultural environment is good or above in research lab (Fig. 1G). Together, more than half of medical students have the research experience in the junior grades and the average time spending in SRIP is one year. In addition, most students are satisfied with the hardware and cultural environment for accomplishing their SRIPs.

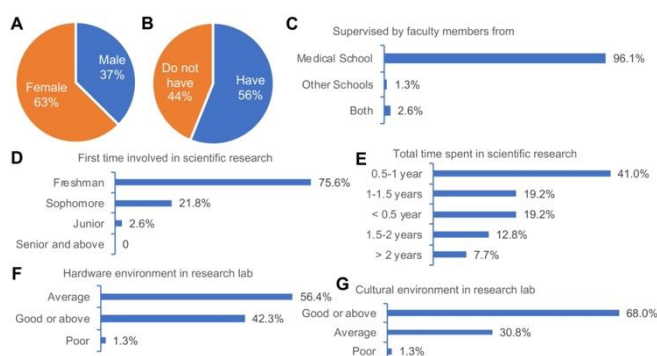


Fig. 1. The basic situation of medical students participating in SRIPs. (A) Gender, (B) Have or do not have experience of participating in SRIPs, (C) Supervised by whom, (D) First time involved in scientific research, (E) Total time spent in research, (F) Hardware and (G) Cultural environment in the research lab.

B. Personal Interest is a Major Motive and Selective Criteria for Research

For the main reasons for participating in SRIP, the results showed that personal interest (43.6%) is the major motive and going with the flow (9%), creative credit (9%), being a medical scientist (5.1%), or awarding scholarship (1.3%) are not the main motives (Fig. 2A). Consistent with the research motives, more than half of the students (52.6%) selected supervisors under the criterion of personal interest and research field. Only a small portion of the students followed the good personality of supervisor (15.4%), previous achievements (14.1%) and high academic standards (5.1%) (Fig. 2B). Almost half of the students (47.4%) did not have specific goals, but for improving skills. Meanwhile, 42.3% of the students had strong goals for academic achievements (Fig. 2C). For the project sources, supervisor-centred projects (68%) were the mainstream, 25.6% of the projects were student-supervisor-agreed and only a very small portion of projects are student-centred (6.4%) (Fig. 2D). These results indicate that personal interest has come to dominate the SRIPs.

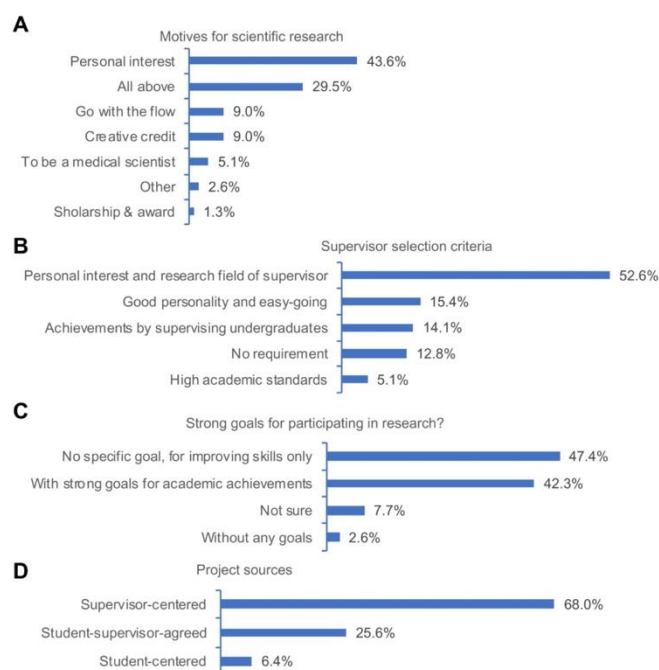


Fig. 2. The motives and requirements for scientific research. (A) Motives for scientific research, (B) Supervisor selection criteria, (C) Goals of participating in research, and (D) Project sources.

C. SRIP is Self-managed and Well Arranged in Medical Students

To investigate how SRIP was conducted, the arrangement and guidance of the research work was evaluated. The results showed that most students (83.8%) arranged the time by themselves, not by supervisors. Only one tenth of the students did an anticlimactic time arrangement (Fig. 3A). Frequent (53.3%) and occasional (31.2%) supervisions by faculty members were the mainstream of the management for SRIPs (Fig. 3B). To accelerate progress of the SRIPs, students could actively report the research results and discuss the problems with their supervisors at every stage of the development. More than half of active reports were made weekly and whenever necessary (Fig. 3C). Based on their activities in the labs, more than half of the students were familiar with the

collaborator's work (Fig. 3D). Under such circumstances, 16.9% of the students had finished a complete project and 57.1% of the students were going to finish their projects prior to the termination of SRIPs (Fig. 3E). These results demonstrate that the SRIP is self-managed by students and well arranged by the research group.

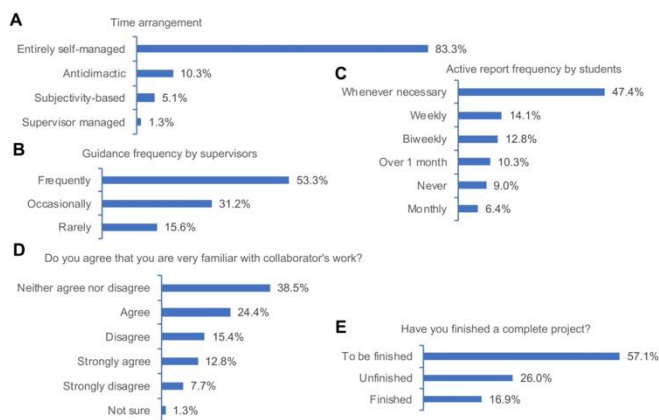


Fig. 3. The quality of SRIP arrangement. (A) Time arrangement, (B) Guidance frequency by supervisors, (C) Active report frequency by students, (D) Response to the understanding of the collaborators' work, and (E) Finish a complete project.

D. Early Scientific Research Training Benefits Students in both Academic and Non-academic Achievements

We surveyed the academic and non-academic achievements of scientific research, the results indicated that the greatest benefit from scientific research might be the ability of doing independent research (16.7%), understanding one's own shortcomings (12.8%), knowledge about medical sciences (12.8%), teaming and collaboration ability (3.9%), gain of friendship (1.3%), or all above (52.6%) (Fig. 4A). Similarly, the greatest non-academic help from scientific research differed in scholarship, independence and personality (Fig. 4B). For the academic achievements, more than half of students who participated in scientific research had received co-author/first-author papers, patents, or awards. However, almost half of the students (49.4%) did not have any academic achievements (Fig. 4C).

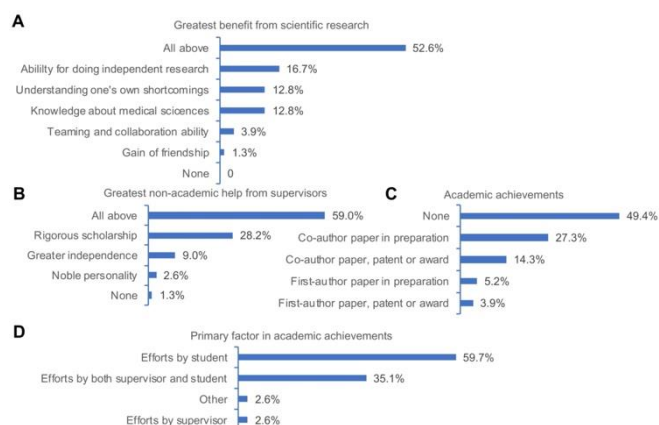


Fig. 4. The assessment of the students' achievements from SRIPs. (A) Greatest benefit from scientific research, (B) Greatest non-academic help from supervisors, (C) Academic achievements, and (D) Primary factor in academic achievements.

To further investigate the impact of SRIP on research productivity, we calculated the direct academic index (DAI) and average AI (AAI), and then we evaluated the relative AI (RAI) for each group. The results showed that the freshman participants had the highest DAI with 41 and the junior participants had the lowest DAI with 1. Meanwhile, the freshman participants reached its highest AAI with 0.706 and the junior participants shared the lowest AAI with 0.333. Taken together, the freshman participants yielded the maximum value for RAI (0.177) and became the most productive group (Table 1). Among the different factors that affect the academic output, 59.7% of the students considered efforts of students as the primary factor, and 35.1% of the students considered efforts of both supervisors and students as the primary factor. Only a very small portion of the students (2.6%) considered efforts of supervisors as the primary factor (Fig. 4D). These findings show that early scientific research training promotes the progress of students in both academic and non-academic achievements.

TABLE I: THE IMPACT OF SRIP ON RESEARCH PRODUCTIVITY

Participants \ AI	DAI	AAI	RAI
Freshman	41	0.706	0.177
Sophomore	9	0.529	0.176
Junior	1	0.333	0.167

AI, academic index; DAI, direct academic index; AAI, average academic index; RAI, relative academic index.

E. A Planned SRIP is Useful, Challengeable, and Supportive for Medical Students

A planned SRIP could provide scientific training in different aspects, such as skills, safety and standards, etc. The vast majority of the students (68.8%) thought the scientific training was useful and 28.6% students considered it was insufficient. Only few students (2.6%) thought it no use to participate in scientific research (Fig. 5A). During doing research work, most of the students (68.4%) began to feel the pressure coming from themselves (Fig. 5B). However, they had their own contributions to the supervisors' labs and wanted to do SRIPs in more labs during the undergraduate period (Fig. 5C and D).

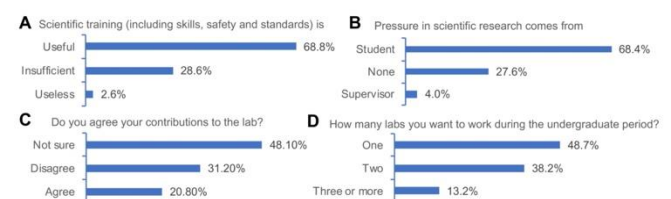


Fig. 5. The analysis of the students' experiences from SRIPs. (A) The usefulness of scientific training, (B) Pressure in scientific research, (C) Agreement about the contributions to the labs, and (D) The number of the labs that students want to work during the undergraduate period.

To evaluate the SRIPs, the overall assessments of research project, supervisor, and research activities were made by medical students. The results showed that more than half of the students (53.9%) regarded the research project as difficult and challengeable, and no one regarded it as very easy (Fig. 6A). Meanwhile, 67.9% of the students selected "excellent" level and 23.1% of the students selected "very good" level for the overall assessment of their supervisors (Fig. 6B). In addition, the great majority of the students gave an above

“helpful” comment on research activities (Fig. 6C). For the research experience, medical students used the positive words, such as “supportive” (36.4%), “friendly” (20.8%), “passionate” (16.9%) and “collaborative” (14.3%), to describe their experience (Fig. 7A). However, the negative words were given as “stressful” (42.3%), “tense” (23.1%), “competitive” (12.8%) to comment on the research experience (Fig. 7B). For better achievements, 72.7% of the students suggested that more cognition and devotion should be done by themselves to improve the undergraduate scientific research (Fig. 7C). In general, these results show that a planned SRIP is useful, challengeable and supportive for medical students, and more scientific training is required to improve the research ability of undergraduates.

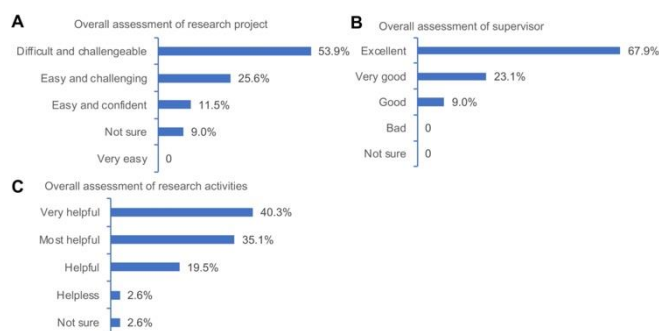


Fig. 6. The overall assessment of SRIPs. (A) Research project, (B) Supervisors, and (C) Research activities.

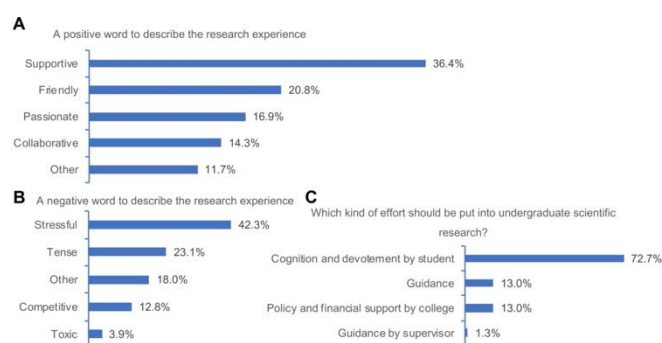


Fig. 7. The subjective assessment of research experience. (A) A positive word to describe the research experience, (B) A negative word to describe the research experience, (C) Efforts should be put into undergraduate scientific research proposed by students.

IV. DISCUSSION

The current work shows that more than half of medical students at Ningbo University School of Medicine participate in SRIPs in the junior grades. Prior to the engagement of research work, students' personal interest is a major motive and selective criteria. Meanwhile, SRIP is found to be self-managed and well arranged in medical students. As a result, early scientific research training benefits students in both academic and non-academic achievements. In addition, the planned SRIP is considered useful, challengeable, and supportive for medical students. These findings reveal the potential value of the wider implementation of SRIP throughout the school years in enhancing the research ability of undergraduate education. Compared to the similar program in other developing countries (Tafur-Cotrino *et al.*, 2014), a planned SRIP carried out at Ningbo University School of Medicine not only improves the research experience, but also

receives both academic and non-academic achievements.

Although there are different medical education systems in different countries, the core goal of medical education is to train eligible medical practitioners, such as clinical doctors. The different national conditions have decided the different training models to cultivate medical students. It is almost impossible for one medical education system to lead the world in medical education and training (Darzi & Kibasi, 2009). To promote the research ability of medical students, different strategies have been employed through the whole medical education phases (Brown *et al.*, 2018; Shen *et al.*, 2016). Take the case of the student research programs, the faculty willingness significantly influences the quality of mentoring undergraduate students (Morales *et al.*, 2016). In current work, most faculty members are willing to supervise the first-year and second-year medical students. Most of students participated in SRIPs have enough time to contact their faculty supervisors to discuss the progress of the research projects without warning. Naturally, this situation is largely dependent on the encouraging policy of scientific research innovation of undergraduates. Interestingly, the international collaborative training programs have important impact in medical students' research ability (Rezhake *et al.*, 2018). Hence, the study design of SRIP is critical in improving research ability. Our work shows that the vast majority of the research projects are supervisor-centered and student-supervisor-agreed, suggesting that the supervision by faculty members is the predominant factor affecting the performance of SRIPs.

The motivations for clinical study participation are usually linked to different types of benefits (Nappo *et al.*, 2013). Prior to participating in scientific research, medical students at Ningbo University School of Medicine often give first priority to their personal interest. Only a small portion of the students really cared about creative credits and scholarships. And so, the students selected the supervisor for their personal interest and research field, not high academic standards. This might show a false impression that medical students had no strong goals of participating in research. In fact, the research environment is extremely important and necessary for scientific discovery (Jorgensen & Hanssen, 2018). Since Ningbo University School of Medicine provided an ease scientific environment for medical students, the research output achieved a success and up to or above expectations.

It is quite clear that the quality improvement education is necessary for medical students. Medical school choice and curriculum change greatly influence the quality of undergraduate education (Malak, 2017; Saiki *et al.*, 2018). The abilities of research innovation and clinical thinking are important aspects of education quality. Toward value-added SRIP, the research outcomes reflect the quality of education to some extent. The benefits from scientific research are divergent (Dacre & Johnson, 2017). Take the case of SRIPs, the ability of doing independent research, understanding one's own shortcomings, knowledge about medical sciences, teaming and collaboration ability, even gain of friendship are the greatest benefits for medical students at Ningbo University School of Medicine. Academic papers, patents, awards are the most common research outcomes in research activities. Beyond that, more remarkable, the non-academic achievements gained by the students are the critical factors

for improving the research ability in undergraduates. In our study, rigorous scholarship, greater independence and noble personality were the major non-academic achievements from SRIPs. Hence, both academic and non-academic achievements are the main forms of student outcomes, suggesting a quality improvement for medical students. Interestingly, most of the medical students thought that they should make more efforts for better achievements. These findings show that a more equal, free and autonomous academic environment will benefit the quality of talent cultivation.

It is necessary to cultivate and develop the innovation ability of college students in quality education and seek the connection between the clinical thinking and the career development among individual medical students. The quality of undergraduate education is largely dependent on students' course experience and research engagement (Brown *et al.*, 2016; Yin & Ke, 2017). To bridge the gap between textbooks and scientific research, the integrated course and evidence-based practice are applied to improve the knowledge, skills and abilities (Ramirez-Velez *et al.*, 2015; Wiegant *et al.*, 2011). For medical students, the participation in research is associated with improved short-and long-term scientific productivity, more informed career choices and improved knowledge about-, interest in- and attitudes towards research (Amgad *et al.*, 2015). Hence, the SRIPs designed for undergraduates are one of the perfect complements beyond the course teaching to promote the research ability of medical students.

V. CONCLUSIONS

In present work, we took a complete and reliable survey to investigate the situation and effect of scientific research on high quality medical education. We found that SRIP was self-managed and well arranged, and more than half of medical students participate in SRIP in the junior grades. Furthermore, a planned SRIP was found to be useful, challengeable and supportive for medical students and the early scientific research training benefits students in both academic and non-academic achievements. These findings demonstrate that a well-designed scientific research training promote the research ability of medical students.

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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