# AC 2009-924: THE PROFESSIONAL TRAINING FEATURES FOR NON-DESTRUCTIVE TESTING GRADUATE STUDENTS

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# The Professional Training Features for Non-Destructive Testing Graduate Students

## Introduction

The Non-Destructive Testing (NDT) specialists carry out a quality exam for various kinds of products, conduct inspection of potential accident industrial objects, and provide their safe exploitation. Such branches of industry as aviation, ground transportation, nuclear power stations, and civil engineering can't even exist without NDT specialists. All people need high quality products, to be protected from terrorism and technogeneous catastrophes. Thus, NDT specialists are desired in any society. Today Ukraine has a lot of objects and constructions which were built many years ago. Such objects as hydroelectric plants, dams, bridges, inflammable stores, and many others need to be inspected for evaluation of their safety. So, the problem of NDT specialist preparation is very important for Ukraine which had Chernobyl catastrophe in the past.

## The features of professional activity

The professional activity of the NDT engineers has distinctive features as compared with common engineers. The fulfillment of complicated tasks with high level responsibility is expected from them. They must have not only high standard of knowledge in professional field, but certain abilities and personal merits which are professionally required. This is the reason to emphasize some features of such profession which have to be taken into consideration at specialist preparation.

First of all, NDT engineers have to be able not only to use the procedure and devices for discovering defects in an object, but have enough competence to take decision about its availability for further exploitation. The wrong decision can lead to human sacrifices. So, NDT engineers must have the higher responsibility for a mistake. Thus, the main features of a specialist are abilities to take decision in specific situation, to be responsible for this decision, and professional skills.

The second, NDT engineers have to demand the stopping of the object exploitation if they discover something wrong in it. So, specialists must have objectivity, persistence, adherence to principles, and so on.

Considering the requirements to the NDT specialists we can specify their abilities: high level of competence included knowledge and skills; understanding the particulars of complicated situations and finding the optimal solution; high professional and social responsibility. Question is: How is it possible to form necessary abilities of future specialists?

## The problems of professional training

NDT is a complex specialty. Specialists have to acquire knowledge from different directions of engineering. Students study, physics of surface, electromagnetic field, optics, acoustics, thermal physics, and nucleus physics. Moreover, they have to know how to use electronics (microprocessors, microcontrollers), programming, and signal processing technique for designing automatic system of NDT. So, the process of forming student's competence becomes complicated by some reasons. First of all, differentiation of the teaching

content may lead to loss the logic connection between subjects. Sometimes student can't perceive the system of knowledge as a whole system. Besides, the loss of subject logic connection complicates forming and development of student's system-logical thinking. As a result, future specialists don't have system perception of specialty, its professional and social aspects.

The second is a contradiction between knowledge extension and time limitation for teaching. It is obvious that the traditional informative method when the instructor tries to deliver large information content becomes ineffective. In any case, this information content won't be enough to provide high level of competence during professional career, because engineering knowledge becomes old very soon. Therefore, it makes sense to develop and stimulate the cognitive interest of students, form the skills, and use necessary information independently.

The third is a contradiction between the principles of knowledge unity and dividing knowledge into fundamental and special. This problem is directly connected with forming professional competence of the future specialists. On the one hand, students have to know fundamental subjects perfectly in order to become proficient. On the other hand, deepening into fundamental knowledge shifts the accent of student preparation and reduces time for studying special subjects which are the basis of professional competence and skills.

**What is the professional competence?**

Now day European Union countries introduce a new system of education. This system of student preparation is directed at forming not only knowledge and skills but special competences also. The traditional system of education is based on tow ways of the educational process organization. The main feature of the first way is content of student training, i.e. **what** exactly instructor delivers, it is at the centre of attention. The second way is based on the process of training, i.e. the main feature is **how** the instructor delivers the course. New system of education is based on the competence method approach which has different result of education. This result is not amount of learned information only. It is also specialists' ability to apply this information to different complicated situations and get missing information independently. In other words, the result of student education is the presence or absence necessary competences.

The problem of competence-oriented education was considered in the papers of European authors - E. Short, Simon Shaw, A. Shelton, W. Hutmacher, T. G. Roos, and others. According to E. Short, competence is combination of knowledge, skills and operation.[1] Simon Shaw gave definition of the eight groups of base skills which were useful for professional activity and daily needs as well.[2] A. Shelton proposed the five groups of key competences which depend on professional activity of a person. The first one depends on psychophysical abilities of a person. These are abilities to attract attention, reaction time, coordination, and others. The second competence group is connected to professional abilities and skills. The third one determines cognition abilities, such as creative thinking and others. The fourth reflects individual abilities - self-reliance, responsibility, and aim at success. The fifth is social abilities – ability to cooperate and connectivity.[3] Description of the term "key competences" was given on European Council symposium in 1996. The report of European experts "Key Competences for Europe" was devoted to definition of five general groups of key competences which were very impotent for student preparation. They are political, social and cultural, communicative, social and informational, and personal competences.[4]

The German scientist Roos T.G. considers that the present-day worker has chance to find job if he possesses of a "competences portfolio". He mast solve a problem instead of fulfill a task.[5]

The issue of education modernization is widely discussed in Ukraine also. According to Ukrainian law, quality of higher education is "total abilities of a graduated person which demonstrate professional competence, value direction, social orientation, and satisfy the personal and public requirements". [6] One of the directions for education modernization is application competence-oriented approach more widely. It means forming activity skills in specific situations, in other words forming professional competence. [7] With regard to tendency of education development, it is proposed general structure of professional competence for specialists (see Fig.1).

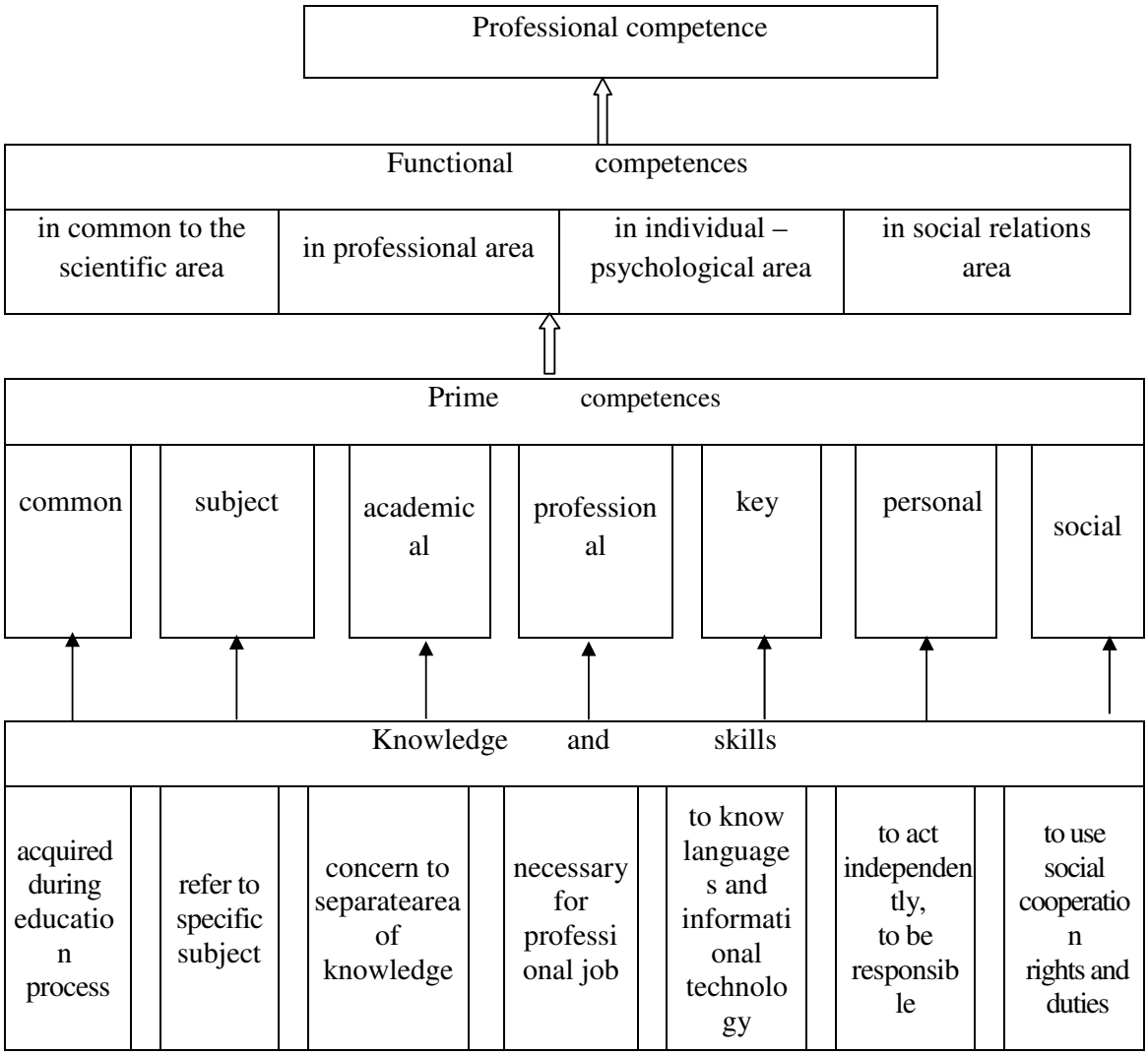


**Figure 1: The structural diagram of specialists' professional competence**

In general the specialists' professional competence is represented as a combination of functional competences in common to the scientific, professional, individual – psychological, and social relation areas. Competence in common to the scientific area is a base of the given

profession. It consists of common, subject, and academical competences. This conception is characterized by specialists' professional knowledge, intellectual activity, ability to analytical think, ability to constructively discharge their obligations, and ability to extend their knowledge. Competence in professional area can be form by professional, academical, key, personal, and other competences. It is characterized by specialists' ability to act on the high level of the specific professional area and foreknowing the results of this acting. Competence in the individual – psychological area is based on personal competences which stimulate development of a personality in the context of a chosen profession. It forms the motivation for development of a tendency to check and evaluate of specialists' activity. The conception of competence in individual – psychological area is characterized by specialists' ability to study without assistance and take decisions. Competence in social relations area is based on social, personal, and key competences which provide for specialists' ability to work in a team, have social responsibility for the results of their professional activity, know and keep traditions, and manage of information and communication technology. Thus, acquired students' knowledge and skills is a base of the future specialists' professional competence.

**Professional competence of NDT specialists**

Accordingly to Bologna Declaration, Ukrainian system of higher education has two levels of specialist preparation: bachelor and master's degree.
Present Ukrainian classification of professional activity in the technical field is divided on: performing, operating, producible- servicing, and researching levels. The specialist model has to describe the set of competences, professional duties, and the level of preparedness to accomplish specific functions.[8]

Taking into consideration mentioned classification and professional activity features of NDT specialists, it is possible to propose the structure of the bachelor and master's professional competence. The typical bachelor's professional activities in the NDT field are: experimental-research, manufacturing- servicing, calculation-design, and administration activities.

Competence in experimental- research activity provides a bachelor with abilities to:
- carry out the research of the testing object models using standard software and mathematical simulation methods;
- realize experiments and analyze their results using given procedure;
- study scientific and technical information.

Competence in manufacturing- servicing activity is proposed bachelor's skills in:
- using NDT devices for inspection of products;
- using monitoring systems for technologic forecasting of the object condition;
- tuning up, installing, and activating software and hardware of NDT devices;
- specifying technical conditions of devices using monitoring devices.

Competence in calculation-design activity provides a bachelor with abilities to:
- calculate and design components of NDT devices;
- check capability of the projects and technical documentations to technical requirements;
- design of technical documentations.

Competence in administration activity provides a bachelor with abilities to:
- certificate and standardize NDT devices;
- organize marketing and selling of NDT devices;
- use economical and administrative methods of management.

Analyzing bachelor's professional activities, it is possible to consider that experimental-research activity belongs to common to the scientific area, manufacturing- servicing and calculation- design activities belong to professional area, and administration activity relates to individual – psychological and social relations areas. Although, this classification is conditional, it is possible to accept it for a base of the bachelor's professional competence structure. It presents on Fig. 2.

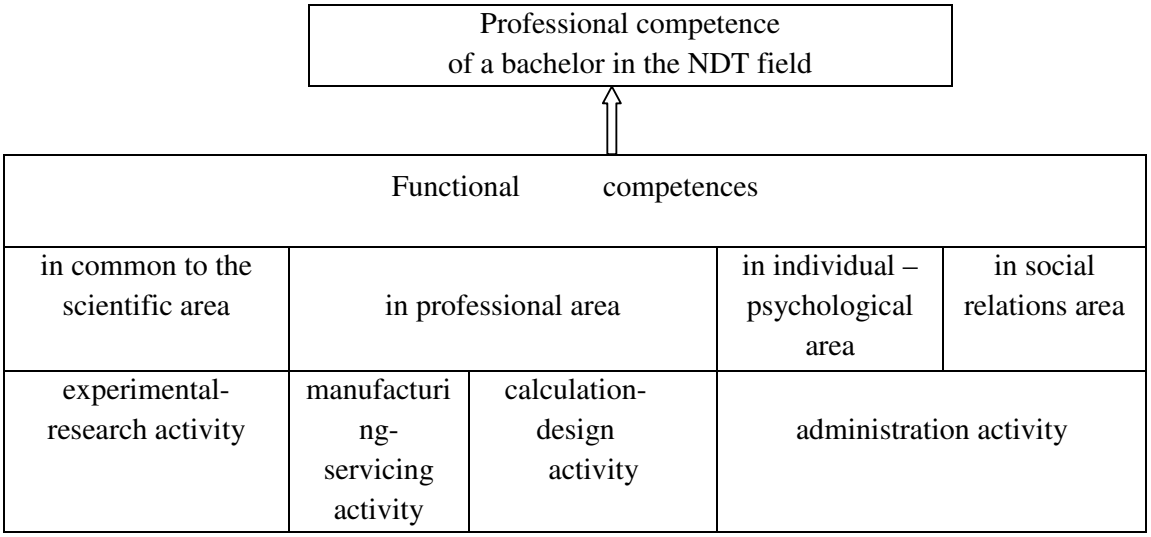


**Figure 2: The structural diagram of the bachelor's professional competence**

It is obviously that specialist must be intellectual developed. Therefore, the footing of the bachelor's professional competence forming must develop students' creative abilities, namely: creative thinking and creative activity.

The master's training program is based on the bachelor's one. It means that a future master is ready to fulfill the work that a bachelor can. The masters have to be preparing for following professional activities in the NDT field: research, design, and management activities.

Competence in research activity provides a master with abilities to:
- create of the mathematical and physical models of NDT devices;
- design procedure of the experiments and test operation.

Competence in design activity is proposed master's skills in:
- analyzing advanced direction of NDT devices development;
- designing technical documentation for manufacturing of NDT devices.

Competence in management activity provides a master with abilities to:
- organize management for improvement and modernization of NDT devices;
- search the optimal solution for making of NDT devices taking into account quality, reliability, and value requirements.

Let's refer research activity to common to the scientific area, design activity to professional area, and management activity to individual – psychological and social relations areas. Then the structural diagram of the master's professional competence looks like in Fig.3.

The master's professional competence has to provide with implementation of an innovation cycle: scientific investigation work – research design work – manufacturing new product. In this case, the master's creative ability displays itself in master's research and innovation activities.

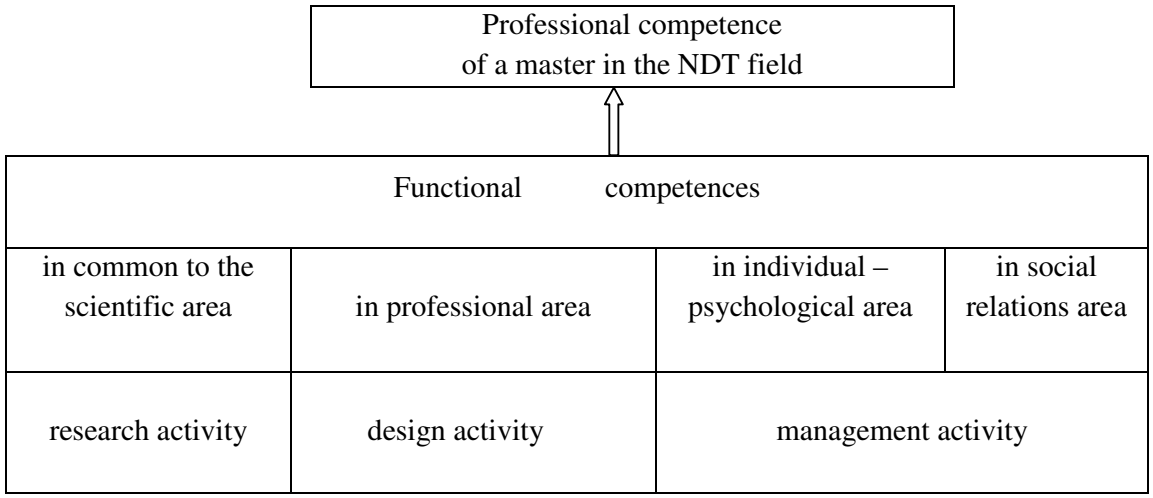


**Figure 3: The structural diagram of the master's professional competence**

**Experience of NDT department of National Technical University of Ukraine "Kiev Polytechnic Institute"**

The Ukrainian system of higher education has different from the USA and European system features. Student preparation in the given specialty starts from the first grade in Ukraine. Thus, students start to study as fundamental as special subjects from the very beginning. The future bachelor studies such different subjects as Ultrasonic, Electromagnetic, Optical, Thermal, and other Methods of Testing during four years. In order to form necessary system of knowledge and skills (see Fig. 2), connect fundamental and applied knowledge, we bring into the curriculum a series of integrated subjects (see **Appendix A**). For example, they are NDT Systems, Microcontrollers in NDT Systems, Scanner Designing for NDT Systems, and others. The content of these subjects helps students to find common features of the different testing methods compare and determine preference and disadvantage each of them, and find the most appropriate field for application.

In order to form students' creative thinking we apply following system. The first-year students get the assignment to prepare abstract of the some topics concerning subjects they study. The aim of this task is to train students to work without assistance and use textbooks and scientific papers as well. This is the beginning of the research motivation forming.

The second- year students get the assignment to write a review on the monograph, book or paper. This work trains students to analyze and pick out the main ideas from the large information content. The third and fourth-year students accomplish term projects devoted to the traditional methods of testing. In these projects students join knowledge about separate testing methods and apply knowledge acquired from the interdisciplinary subjects. It helps to form system thinking and high level of professional skills.

It is known that any system of education consists of two aspects connected to each other: theoretical lectures and practical training. Future engineers use laboratory equipment for their

training. That is why our system of creative thinking forming combines student operation on real devices with computer simulation. This principle is a base of student laboratory training for following subjects: Electronics, Microprocessors, and Signal Processing. Working with system "device- computer", students have possibility not only to see confirmation of known laws and rules, but to implement research their models, change parameters, and create new models. The heuristic level of students' creative activity is formed on this stage.

Computer simulation is used in laboratory training for subjects: Electromagnetic and Thermal NDT Methods. For this task students use such interactive software packages as MathLab and FemLab. This training allows students to make measurement virtually and understand the testing procedure as well. Students study influence of various factors on the inspection result. They can research influence of flaw parameters (depth, size, and physical properties) on the inspection procedure. Proposed laboratory training gives possibility to observe processes which are invisible for a human eye and better understand wave distribution in the test object.

The monitoring of students' preparation quality is provided once a year for the fourth-year students. The monitoring procedure and results are brought in the **Appendix B**.

## Conclusion

Present-day reality needs new well founded models for engineering education which take into account features of student's personality and requirements of industry. Forming of specialists' professional competence is one of the important problems of future engineer preparation. The specialist's professional competence is a complicated factor which includes prime competences based on acquired knowledge and skills. The footing of the specialists' professional competence forming is development of students' creative abilities.

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**Appendix A: The curriculum of the bachelor training program (235.5 Credits)**

**Freshman**

| The 1-st term | | The 2-nd term | |
|---|---|---|---|
| Philosophy 1 | 2.5 | Cultural Science | 1.0 |
| History of Ukraine | 1.5 | Ukrainian Language | 1.0 |
| Foreign Language | 2.0 | Foreign Language | 2.0 |
| Mathematics 1 | 6.0 | Mathematics 2 | 6.0 |
| Gen. Physics 1 | 5.0 | Gen. Physics 2 | 5.0 |
| Computer Programming 1 | 4.0 | Gen. Chemistry | 4.0 |
| Engineering Graphics 1 | 4.0 | Computer Programming 2 | 4.0 |
| Material Science | 3.0 | Engineering Graphics 2 | 4.0 |
| Informatics | 1.5 | Theoretical Mechanics 1 | 3.0 |
| Total | 29.5 | Total | 30.0 |

**Sophomore**

| | | | |
|---|---|---|---|
| Philosophy 2 | 2.5 | Foreign Language | 2.0 |
| Foreign Language | 2.0 | Ecology | 1.5 |
| Mathematics 3 | 6.0 | Mathematics 4 | 6.0 |
| Theoretical Mechanics 2 | 3.0 | Solid-State Physics 2 | 2.5 |
| Solid-State Physics 1 | 2.5 | Metrology | 3.0 |
| Applied Mechanics 1 | 3.0 | Applied Mechanics 2 | 3.0 |
| Electro technology 1 | 4.0 | Electro technology 2 | 3.5 |
| Electrical NDT 1 | 3.0 | Electronics 1 | 4.0 |
| Computer Designing 1 | 4.0 | Electrical NDT 2 | 3.0 |
| | | Computer Designing 2 | 3.0 |
| Total | 30.0 | Total | 31.5 |

**Junior**

| | | | |
|---|---|---|---|
| Economics | 2.0 | Psychology | 1.5 |
| Foreign Language | 2.0 | Sociology | 1.5 |
| Safety Regulations | 3.0 | Foreign Language | 2.0 |
| Electronics 2 | 4.0 | Electronics 3 | 4.5 |
| Automatic Control Theory | 4.0 | Microprocessors | 7.5 |
| Signal Processing | 6.0 | Electromagnetic NDT 1 | 4.5 |
| Electromagnetic Field Theory | 4.0 | Digital Technique | 7.0 |
| Scanner Designing | 3.0 | Microcontrollers | 2.0 |
| Total | 28.0 | Total | 30.5 |

**Senior**

| | |
|---|---|
| Civil Law | 1.5 |
| Foreign Language | 2.0 |
| Electromagnetic NDT 2 | 4.5 |
| Ultrasonic NDT 1 | 4.5 |
| Radiography | 3.0 |
| Thermal NDT | 6.0 |
| Probability of Detection | 2.0 |
| NDT Systems | 3.0 |
| Total | 26.5 |

| | |
|---|---|
| Ultrasonic NDT 2 | 4.0 |
| Optics | 4.0 |
| Mathematical Simulation | 4.0 |
| Digital Information Processing | 4.0 |
| Pre- Project Design Practice | 4.5 |
| Project Design | 9.0 |
| Total | 29.5 |

**Appendix B: The monitoring procedure and results of NDT students' quality preparation**

The monitoring procedure is based on the formula:

$$\mathbf{I_{tot} = I_1 + I_2 + I_3}$$

Where:

**$I_{tot}$ -** is the total index of students' quality preparation,
**$I_1$ –** is the index of students' permanent knowledge,
**$I_2$ –** is the index of students' graduation work quality,
**$I_3$ –** is the index of labor-market opinion poll.

The index **$I_1$** shows the results of common testing which include the following subjects:

a) basic disciplines (mathematics and physics);
b) informatics and programming;
c) foreign language;
d) professionally oriented disciplines;
e) special disciplines.

The index **$I_2$** determines correspondence of the graduation work to the University requirements.

The index **$I_3$** contains following factors:

a) standard of special training;
b) standard of practical training;
c) standard of possessing of present-day information technologies and software tools;
d) standard of foreign language possessing;
e) availability to study and be able to learn fresh information from their profession.

| The monitoring results of NDT students' quality preparation | | | | |
|---|---|---|---|---|
| Year | Index of permanent knowledge ($\mathbf{I_1}$) | Index of graduation work quality ($\mathbf{I_2}$) | Index of labor-market opinion poll ($\mathbf{I_3}$) | Total index of specialists' quality preparation ($\mathbf{I_{tot}}$) |
| Fall 2005 | 39.433 | 3.278 | 13.356 | 56.067 |
| Spring 2006 | 39.923 | 3.779 | 13.450 | 57.152 |
| Fall 2006 | 41.426 | 4.106 | 13.500 | 58.866 |
| Spring 2007 | 41.600 | 4.512 | 14.080 | 60.192 |
| Fall 2007 | 41.650 | 4.547 | 16.101 | 62.298 |
| Spring 2008 | 43.031 | 4.601 | 16.932 | 64.564 |
| Fall 2008 | 44.010 | 4.589 | 18.012 | 66.611 |