Enlightenment Teaching of Engineering Cognition for Junior High School Students Based on Linear Function

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Abstract. The earlier the enlightenment teaching of engineering cognition is conducted, the better for fostering engineering talents. In China, the knowledge about linear function or univariate equation is taught to the students in their junior high school period. This should be a precious opportunity for enlightenment teaching of engineering based on application of linear function in routine life. In the present investigation, an example is shown how to explain the application of linear function in routine life and its meaning in chemical and material engineering field. The example is about the quantitative detection of a blue dye’s concentration in the polluted water. Meanwhile, an advanced nanomaterial - electrospun nanofibers was explored to treat the polluted water. The experiments were very vivid, greatly deepening the impressions of the junior high school students on the linear equation, enlightening their engineering cognition from a standpoint of mathematics. Enlightenment teaching of engineering cognition can be carried out on the junior high school students when they are taught about the fundamental mathematics knowledge.

The Important Role of Mathematics in Engineering

To a certain meaning, engineering is an application of science and mathematics [1]. Through this application, the material and energy properties of nature can be made efficient, reliable and useful to human beings in the shortest time and with the least human and material resources through various structures, machines, products, systems and processes. In modern society, the word "engineering" can be defined as the process of transforming an existing entity (natural or man-made) into an artificial product of anticipated use value through an organized group of people, using relevant scientific knowledge and technical means, based on a set of envisaged objectives.

Fig. 1 The important role of mathematics in all kinds of engineering disciplines

Engineering knowledge is mainly based on mathematics, physics, chemistry, and the resulting materials science, solid mechanics, fluid mechanics, thermodynamics, transport process and system analysis. According to the relationship between engineering and science, all branches of engineering have a wide variety of functions, such as research (applying concepts, principles and experimental
techniques of mathematics and natural science to explore new working principles and methods),
development (solving various problems encountered in the application of research results to practical
processes), design, construction, production, operation, and management.

Shown in Fig. 1 is a diagram of the important role of mathematics in many different engineering
branches such as bioengineering, marine engineering, civil construction engineering, environmental
microbial engineering, water conservancy engineering, chemical engineering and genetic
engineering. The mathematics knowledge studied by the students in their junior school is very
fundamental thing. Although it is relatively easy, its usefulness in enlightenment teaching of
engineering cognition for them should be tremendous. Here, based on linear function studied in the
seventh grade, some teaching materials can be concluded for the students to achieve some feelings
about material engineering and chemical engineering.

The Linear Equation Lessons Of Junior High School Students in China

Schools in China are generally divided into primary schools, secondary schools (or middle schools)
and universities. Secondary schools are divided into junior high schools and senior high schools.
Students in junior high schools are called junior high school students. Junior middle school is the
primary stage of middle school. It is usually three years, but some areas are four years (compared with
primary school is five or six years), including junior one, junior two and junior three. Some areas are
called seventh grade, eighth grade and ninth grade. Junior high school is the beginning of adolescence,
the last three years of nine-year compulsory education, and a transitional stage towards senior high
school. Junior high school is a part of compulsory education, which is usually promoted from the
sixth grade of primary school.

Entering junior high school, students learn different courses from primary school. Students will be
exposed to a number of new learning subjects. The new courses in junior high school include history,
geography, physics, chemistry, biology and other subjects, and each grade will change some subjects.
Chinese, Mathematics, English, Morality and Rule of Law will run through junior high school for
three years. Geography, biology and history will be held in the seventh grade, physics in the eighth
grade and chemistry in the ninth grade. The reason why the junior middle school curriculum is
arranged in this way is mainly considering the student's acceptance ability. The students who have
just entered the junior middle school are still influenced by the learning thoughts and habits of the
primary school. Therefore, it is not suitable to set up theoretical subjects such as physics and
chemistry in the junior middle school, and need junior middle school mathematics knowledge as a
foundation.

Similar with physics and chemistry, mathematics is the foot-stone of all kind of engineering. Almost all the mathematics equations and functions can find their physical meaning for engineering
applications. One of the most frequent example is linear equation. The Linear function in the seventh
grade, he analytic formula of the linear function is: y=ax+b, where a is the slope, not 0; x is the
independent variable, b is the intercept of y axis. Both a and b are constant. A function is not a number,
which refers to the relationship between two variables in a process of change. In a linear function, the
two variables have a certain linear relationship. The key element is the slope. When the the unknown
slope in the analytic formula is determined, the analytic formula of a linear equation is achieved.
Although this piece of mathematical content is simple, which should be taught to the students in the
junior high school. It is a very useful teaching materials for providing them enlightenment teaching of
engineering cognition.

The Enlightenment Teaching of Chemical Engineering Cognition Based the Applications of
Linear Function in Determining the Concentration of Solute in a Certain Solution

Combining learning with practice and being diligent in learning, we should accurately grasp the
essence of abstract concepts and understand the evolution process of abstraction from actual model to
theory. For the theoretical knowledge we have learned, we should seek its concrete examples in a
wider scope, make it concrete, and apply the theoretical knowledge and thinking methods we have learned to practice as far as possible. The application of linear equation in chemical engineering about solute concentration is just an excellent example for this trend.

![Diagram](image-url)

**Fig. 2** Linear function for determining the concentration of solute in a certain solution.

Shown in Fig. 2 is a typical engineering idea for exploring linear equation in chemical analysis. Although a compound’s concentration (C) cannot be measured directly, it has absorbance of a certain wavelength (A). Thus, a series of standard solutions with known concentrations can be prepared. Their absorbance can be determined correspondingly. Then, their relationship can be regressed as \( A = mC + n \). Thus, a linear equation with concrete engineering meaning is successfully built.

Based on Beer-Lambert Law, a traditional physical method [2-5], i.e. ultraviolet-visible spectrosCOPY, can be utilized to achieve the absorbance value. Beer-Lambert Law can also be expressed as a linear function as \( A = \log(I/I_0) = \varepsilon lc \), where \( A \) = absorbance of the solution at a certain wavelength, \( I_0 \) = the intensities of the incident light, \( I \) = the intensities of the transmitted light, \( l \) = the path length of the absorbing in centimeters, \( c \) = the concentration in moles per liter, and \( \varepsilon \) = the molar extinction coefficient. From the principle, it is clear that the absorbance of the solution at a certain wavelength has a linear relationship with the concentration of solute in the solution. This is because \( \varepsilon \) is always a constant for a certain simple substance and \( l \) can be fixed at a constant value, e.g. 1 cm.

When a series of standard solutions are prepared with the known concentrations, they can be scanned to achieve the scanning curves. Shown in Fig. 3, when the concentrations of the solute, i.e. a blue dye, are varied from 5 to 10, 15 and 20 \( \mu g/mL \) (the variable of the x-axis), the y-axis variable, i.e. the absorbance of the solution gradually increase corresponding. The maximum absorbance is at a wavelength of 664 nm, by which the blue color can be shown. For detection accuracy, the absorbance values of different concentrations of the blue dye solutions can be exploited to build the calibration curve (or standard linear equation) for measuring the concentrations of samples with unknown blue dye concentrations.

![Diagram](image-url)

**Fig. 3** The scanning curves of solutions with different concentration of blue dye

**Fig. 4** The standard linear equation

The standard linear equation between the blue dye concentration and its absorbance at the maximum wavelength of 664 nm is shown in Fig. 4. The linear relationship is clear for between the absorbance (\( A \)) and the concentration of blue dye in the solutions (\( C \)). The linear equation: \( A = 0.0975 + 0.1289C \) has a correlation coefficient of \( R = 0.9989 \), suggesting a very nice linear relationship between the two variables within a concentration range of 4 to 20 \( \mu g/mL \).
The above-mentioned practice has a close relationship with the junior middle school students’ routine life and should be easy for them to understand the whole process, in which a linear relationship can be built for reflecting a causal relationship. This knowledge belongs to the field of chemical engineering, particularly the analytical chemical engineering. The combination of this practice with the lesson teaching about linear function should make the students grasp the fundamental mathematics knowledge from a theoretical level to a practical level, which is just an enlightenment teaching of chemical engineering cognition based the applications of linear function in determining the concentration of solute in a certain solution.

The Enlightenment Teaching of Material Engineering Cognition Based the Applications of Linear Function in Treating the Dye-Polluted Water Using Electrospun Nanofibers

The applications of linear equation built from a standpoint of chemical engineering can be further moved forward to the related material engineering field, to the advanced functional nanomaterials. Shown in Fig. 5 is a typical process that electrospun nanofiber mats are explored to absorb blue dye from the model polluted water. A comparison is clear that the electrospun nanofibers can absorb blue dye from the water. The blue color is significantly reduced after several minutes of being immersed in the polluted water with blue dyes.

An electronic scanning microscopic image of the nanofiber mat indicates that the electrospun nanofibers have a typical 3-D web structure with an unique properties of small diameter (about 570±120 nm by estimation), huge porosity, and the functional inorganic particles for degrade the blue dyes are scattered on the surface of the nanofibers, which has been broadly reported in literature [6-11].

Although the concentrations of blue dye in the polluted water can not be directly detected using instrument. Their absorbance values can be measured. Thus based on the built standard linear equation and the measured A values of unknown samples, the concentrations of blue dye before and after treated using electrospun nanofiber mats can be calculated through the linear equation, which is exhibited in Fig. 6.

![Fig. 5 The absorbance of electrospun nanofiber mats on the dye-polluted water.](image1)

![Fig. 6 The calculation of dye concentration and the treatment efficiency using the linear function](image2)

The measured A values for the original polluted solutions and treated solutions using electrospun nanofibers are 1.7861 and 0.9611, respectively. The calculated concentrations for them are 13.1 and 6.7 μg/mL, respectively. The absorbance ratios for the experimental 10 minutes is (13.1-6.7)/13.1×100%=48.85%. These things happened before the eyes of junior high school students can impress them a lot. Not only the knowledge of linear equation can be strengthened, but also their interests may be provoked through the combinations of their mathematics knowledge and the advanced functional nanomaterials. What is more, this kind of enlightening teaching should promote the students to think more about the related advanced techniques such as coaxial [12-15], side-by-side [16], tri-axial [17], modified tri-axial [18-20], and also multifluid electrospinning processes [21].
Based on the above-mentioned processes, an enlightenment teaching about material engineering cognition can be facile to be implement. They can understand that the functional nanofibers can be created using the electrospinning process, and certainly, their enlightenment teaching lessons can also expanded to other advanced electrohydrodynamic atomization techniques such as coaxial electrospraying [22], and modified coaxial electrospinning [23-27].

Summary

Based on the fundamental mathematics knowledge about linear equation, which is taught to the junior high school students in the seventh grade in China, we have shown two examples about the enlightenment teaching of engineering cognition for junior high school students. One is about the enlightenment teaching of chemical engineering and the other is the enlightenment teaching of material engineering. The strategies explored here should be useful for connecting the mathematics knowledge with routine life, promoting the teaching effects of the knowledge on the students, and enlightening their engineering cognition.

References

[1] D.G. Yu, J.J. Li, G.R. Williams, M. Zhao, Electrospun amorphous solid dispersions of poorly water-soluble drugs: A review, J. Control. Release 292 (2018) 91-110.
[2] T. Hai, X. Wan, D.G. Yu, K. Wang, Y. Yang, Z.P. Liu, Electrospun lipid-coated medicated nanocomposites for an improved drug sustained-release profile, Mater. Des.162 (2019) 70-79.
[3] X.Y. Li, Z.B. Zheng, D.G. Yu, X.K. Liu, Y.L. Qu, H.L. Li, Electrosprayed spherical ethylcellulose nanoparticles for an improved sustained-release profile of anticancer drug, Cellulose 24 (2017) 5551-5564.
[4] Q. Wang, D.G. Yu, L.L. Zhang, X.K. Liu, Y.C. Deng, M. Zhao, Electrospun hyromellose-based hydrophilic composites for rapid dissolution of poorly water-soluble drug, Carbohydr. Polym 174 (2017) 617-625.
[5] W. Huang, Y. Yang, B. Zhao, G. Liang, S. Liu, X.-L. Liu, D.G. Yu, Fast dissolving of ferulic acid via electrospun ternary amorphous composites produced by a coaxial process, Pharmaceutics 10 (2018) 115.
[6] Y.H. Wu, D.G. Yu, H.P. Li, X.Y. Wu, X.Y. Li, Medicated structural PVP/PEG composites fabricated using coaxial electrospinning, e-Polymers 17 (2017) 39-44.
[7] Z. Zhang, W. Li, G. Wang, Y.L. Qu, D.G. Yu, Electrospun 4th generation solid dispersions of poorly water-soluble drug utilizing two different processes, J. Nanomater. 2018 (2018) 2012140.
[8] H. Zhou, Z. Shi, X. Wan, H. Fang, D.G. Yu, X. Chen, P. Liu, The relationships between process parameters and polymeric nanofibers fabricated using a modified coaxial electrospinning, Nanomaterials 9 (2019) 843.
[9] X. Liu, W. Shao, M. Luo, J. Bian, D.G. Yu, Electrospun blank nanocoating for improved sustained release profiles from medicated gliadin nanofibers, Nanomaterials 8 (2018) 184.
[10] Y. Xu, J.J. Li, D.G. Yu, G.R. Williams, J.H. Yang, X. Wang, Influence of the drug distribution in electrospun gliadin fibers on drug-release behavior, Eur. J. Pharm. Sci. 106 (2017) 422-430.
[11] Y. Yang, T. Zhu, Z. Liu, M. Luo, D.G. Yu, S.W. Annie Bligh, The key role of straight fluid jet in predicting the drug dissolution from electrospun nanofibers, Int. J. Pharm. 569 (2019) 118634, 2019.
[12] M. Wang, T. Hai, Z. Feng, D.G. Yu, Y. Yang, S.W. Annie Bligh, The relationships between the working fluids, process characteristics and products from the modified coaxial electrospinning of zein, Polymers 11 (2019) 1287, 2019.

[13] Y.Y. Yang, Z.P. Liu, D.G. Yu, K. Wang, P. Liu, X. Chen, Colon-specific pulsatile drug release provided by electrospun shellac nanocoating on hydrophilic amorphous composites, Int. J. Nanomed. 2018 (2018) 2395-2404.

[14] J.J. Li, Y.Y. Yang, D.G. Yu, Q. Du, X.L. Yang, Fast dissolving drug delivery membrane based on the ultra-thin shell of electrospun core-shell nanofibers, Eur. J. Pharm. Sci. 107 (2018) 195-204.

[15] Q. Wang, D.G. Yu, S.Y. Zhou, C. Li, M. Zhao, Fabrication of amorphous electrospun medicated-nanocomposites using a Teflon-based concentric spinneret, e-Polymers 18 (2018) 3-11.

[16] K. Wang, X.K. Liu, X.H. Chen, D.G. Yu, Y.Y. Yang, P. Liu, Electrospun hydrophilic Janus nanocomposites for the rapid onset of therapeutic action of helicid, ACS Appl. Mater. Interfaces 10 (2018) 2859-2867.

[17] X. Liu, Y. Yang, D.G. Yu, M.J. Zhu, M. Zhao, G.R. Williams, Tunable zero-order drug delivery systems created by modified triaxial electrospinning, Chem. Eng. J. 356 (2019) 886-694.

[18] Y. Yang, W. Li, D.G. Yu, G. Wang, G.R. Williams, Z. Zhang, Tunable drug release from nanofibers coated with blank cellulose acetate layers fabricated using tri-axial electrospinning, Carbohydr. Polym. 203 (2019) 228-237.

[19] D.G. Yu, J.J. Li, M. Zhang, G.R. Williams, High-quality Janus nanofibers prepared using three-fluid electrospinning, Chem. Commun. 53 (2017) 4542-4545.

[20] K. Zhao, W. Wang, Y. Yang, K. Wang, D.G. Yu, From Taylor cone to solid nanofiber in tri-axial electrospinning: Size relationships, Results Phys. 15 (2019) 102770.

[21] D.G. Yu, M. Wang, X. Li, X. Liu, L.M. Zhu, S.W. Annie Bligh, Multifluid electrospinning for the generation of complex nanostructures, WIREs Nanomed. Nanobiotechnol. (2019) DOI:10.1002/wnan.1601.

[22] Y.Y. Yang, M. Zhang, Z.P. Liu, K. Wang, D.G. Yu, Meletin sustained-release gliadin nanoparticles prepared via solvent surface modification on blending electrospaying, App. Surf. Sci. 434 (2018) 1040-1047.

[23] D.G. Yu, X. L. Zheng, Y. Yang, X. Y. Li, G.R. Williams, M. Zhao, Immediate release of helicid from nanoparticles produced by modified coaxial electrospaying, Appl. Surf. Sci. 473 (2019) 148-155.

[24] Y.Y. Yang, M. Zhang, K. Wang, D.G. Yu, pH-sensitive polymer nanocoating on hydrophilic composites fabricated using modified coaxial electrospaying, Mater. Lett. 227 (2018) 93-96.

[25] Z.P. Liu, Y.Y. Zhang, D.G. Yu, D. Wu, H.L. Li, Fabrication of sustained-release zein nanoparticles via modified coaxial electrospaying, Chem. Eng. J. 334 (2018) 807-816.

[26] W. Huang, Y. Hou, X. Lu, Z. Gong, Y. Yang, X.J. Lu, X.L. Liu, D.G. Yu, The process–property–performance relationship of medicated nanoparticles prepared by modified coaxial electrospaying, Pharmaceutics 11 (2019) 226.

[27] K. Wang, H.F. Wen, D.G. Yu, Y. Yang, D.F. Zhang, Electrospayed hydrophilic nanocomposites coated with shellac for colon-specific delayed drug delivery, Mater. Des. 143 (2018) 248-255.