

# *VisEdu: Visual Analytics of Study Condition in Primary and Middle Schools*

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**Abstract:** Most of primary and middle schools have established their own database, but not making the full use of it. Apart from student identity information and achievements, subject selection data and student behavior data deserve more research and analysis. First, there is a connection between the different types of education data, which enables educators to observe students learning status more objectively. Second, tapping students' preferences in subject selection under the new college entrance examination policy can assist educators in optimizing instructional design. To realize these, we present VisEdu, an interactive visual analytics system to help educators visualize student behavior data, learning effect data and subject selection data and provide students with the best guidance. In particular, this paper proposes a multi-factor fusion method of student personal learning assessment based on AHP model. It combines students' performance fluctuations with their behavior, so as to present a most comprehensive feedback to educators. We demonstrate the usability of our framework with three case studies from real-world campus.

## 1. Introduction

Many schools have collected massive data on educators, students and subjects to establish information platforms. Most platforms purely provide storage, statistics and query services while the connection between the different types of education data might be ignored. For example, student with low attendance will receive decreasing scores [1]. To this end, there is a strong demand for schools to establish an efficient system to connect students' behavior data and learning effect data for mining and analysis.

In large-class teaching, it is difficult for educators to pay attention to the fluctuation of each student's learning status. Richard Saul Wurman pointed out that a great deal of information that fills our senses every day is not scattered information, but only data. [2]. Information visualization provides users with no more simply accumulation of information, but a friendly experience of browsing and exploration. People can immediately discover the objective laws hiding in data when it

is presented in a visual form [3]. Visualizing data enables educators to notice students' dynamics and offer help in time. Therefore, an interactive visualization system is designed to meet common analysis requirements in the teaching process of primary and middle schools. Meanwhile, data sets in reality are used to verify the effectiveness of the system.

Nevertheless, the problem of educators not assessing the learning status of students scientifically and reasonably remains unsettled. The existing assessment of students' learning is mainly based on the test scores [4], rather than comprehensive assessment from multiple aspects. Thus, this paper introduces the AHP model, which makes full use of human analysis, judgment and comprehensive ability to decompose complex problems into multiple factors and form a multilevel model [5]. The criteria such as students' academic performance, attendance, and consumption are compared two at a time, through pair-wise comparisons, to determine the relative importance in the hierarchy.

Designing such a student personal learning assessment system is full of challenge. First, the same increase in scores does not necessarily mean the same degree of efforts that students put. Second, achieving the same increase in scores might have different levels of difficulty and should be considered different. For example, it is more difficult to raise the score from 90 to 95 than from 60 to 65. Hence, we take the degree of progress as one of the criteria of student personal learning assessment, and provide the measurement of progress degree for instructors to objectively assess students according to different learning conditions. We believe this will promote students' motivation in learning and enhance their sense of identity and self-confidence.

In this paper, we introduce VisEdu, an interactive visualization system to analyze the education data, which employs the APH model. VisEdu consists of three interfaces, namely, the student scale and the class scale to provide objective assessments of students and subject scale to guide the teaching plan. Furthermore, case studies based on real data sets of Ningbo Xiaoshi middle school are conducted and several educational instructors are interviewed to evaluate the system. The results and feedback received demonstrated the value of VisEdu.

The contributions of this work are summarized as follows:

- Use the data set of middle school students' learning situation in the traditional teaching environment for the first time.
- Design a student personal learning assessment model based on the AHP model.
- Build an interactive visual analytics system to analyze the education data.

## 2. Related Work

### 2.1. Educational Data Mining

Educational mining research on traditional teaching environments was popular in the early days. Machine learning or statistical techniques are usually used to analyze the data collected by traditional educational research methods (such as interviews, observation records, etc.) [6]. For instance, Godwin KE, Almeda MV, Petroccia M, Baker RS, Fisher AV. observed the classroom performance of 22 primary school students and then used regression tree algorithm to discover the relationship between the teaching form and students' distraction [7]. However, such methods often analyze from just one angle, lacking the exploration of the data as a whole.

In recent years, driven by popularity of digital education, distance learning and Web 2.0, educational data mining has begun to attract more and more researchers' attention. Qing Chen et al. designed the ViSeq system to explore the impact of different learning activities order on the effect of online learning [8]. David Monllaó Olive et al. predicted the risk value of different students dropping out of the MOOC platform based on a supervised learning framework [9]. Cerezo, Rebeca & Bogarín, Alejandro & Esteban, María & Romero and Cristóbal applied the Inductive Miner

algorithm to the field of education and excavated the learning model of excellent students and those of failed students in online learning [10]. Eyhmus Aydoğdu used artificial neural networks to predict students' final grades in the online learning environment and explored the factors that influence students' online learning achievements [11]. It is clear to see that most researchers are currently focusing on the analysis of learning behaviors in online education while lack analysis of data from traditional environment.

Therefore, for the problems above, our work targets the analysis of learning behavior data and learning effect data in traditional teaching environment, which contributes to better understand of data sets from a global perspective through interactive methods.

## **2.2. Data Visualization Analysis in Traditional Teaching Environment**

In educational data mining, visualization technology displays information and knowledge visually to help people understand educational data more intuitively. With the increase of education data collection channels, visualization has become an indispensable tool for analyzing educational big data. Gama, Sandra & Gonçalves and Daniel explored the correlation between different university courses through multilevel visualization technology [12]. Tiago Martins, Tiago & Gonçalves, Daniel & Gama and Sandra designed a visualization system to track the evolution of the degree and curriculum of the Universidade de Lisboa [13]. Wang Y et al. used cluster analysis and correlation analysis to mine the data information of art examinees and displayed the age, geographical and gender distribution characteristics of art examinees in a visual way [14]. Gan Xiaoya, Liu Kan and Liu Ping used multi-dimensional parallel coordinate axes to visually analyze the relevance of reading, listening and writing scores in English tests, and based on this, gave study suggestions on enhancing the comprehensive ability of English [15].

To sum up, the data visualization content in the traditional teaching environment is still concentrated on the course setting or the problem of unilateral data such as a subject and an exam. Therefore, this paper takes students as the main part of visual analysis and aims to design an effective and easy-to-use visual system to analyze academic data from the student scale, class scale and elective scale, to assist educators to better grasp students' attendance, consumption and other multi-angle statistics information which can improve the management level of educators.

## **2.3. Students Personal Learning Assessment**

Student personal learning assessment is made under the conditions of detailed, scientific and standardized collection, processing and analysis. Its purpose is to promote the overall development of students [16]. It should be noted that the fundamental purpose of student assessment is to promote the overall development of students, not to divide students into different grades [17]. The existing student evaluation has the following problems.

### **2.3.1. The Assessment Content is Single.**

Most schools only focus on the assessment of students' academic performance which means evaluate students according to their performance.

### **2.3.2. The Assessment Method is Single.**

Most schools still take the form of voting and teacher scoring for assessment.

### 2.3.3. Poor Guidance.

Most schools lack formative assessment of students and only focus on result assessment which result in that they cannot adjust teaching plans in time.

Student assessment should be a developmental assessment. It should change with the behavior of students [18]. The comprehensive assessment system of students based on the AHP model proposed in this paper combines student performance, progress and behavior assessment. And the system evaluates students based on the dynamic calculation of all aspects of the students' data within a certain period of time. Students can understand their own performance through these scores and the teachers can use the student's assessment results as bases to guide students' daily learning and timely interfere with students' abnormal behavior.

## 3. Problem Characterization

In this section, we first describe the data content of the data set, then summarize the analytics tasks, and finally identify three major design maxims.

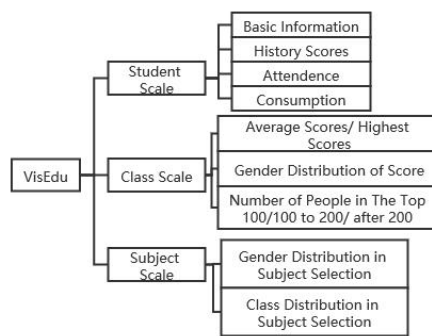


Figure 1: Interactive visualization system of student personal learning assessment.

### 3.1. Data Description and Task Analysis

This paper uses the education data of Ningbo Xiaoshi Middle School from 2013 to 2019, which contains student information, attendance event information, attendance type information, grade information and exam type information for each class and subject in the past five years. According to the visualization task, this paper standardizes the test scores with different full scores to facilitate subsequent comparative analysis. The data content is mainly divided into three categories, as shown in Figure 1.

Our task analysis is based on common data analysis requirements in traditional teaching environment and feedback from educators. The detailed description of all the tasks are as follows:

T1. Can we provide an overview of the student's basic information and get an effective assessment score for the students' learning status?

Scientific and reasonable evaluation of students' learning status is the main problem in the field of education. In large-scale teaching, it is very difficult for educators to pay attention to each student and make a comprehensive and objective assessment of each student, which will to some degree weaken students' motivation in learning. This overview allows educators to quickly understand students' recent learning status.

T2. How is the student's academic performance in each subject? Does the partial branch in learning exist?

Every student has to face a lot of subjects in high school. They have different learning abilities in different subjects. However, the balanced development of students can lay a solid foundation for further learning. Therefore, a visualization of students' academic performance in various subjects are required.

T3. What is the trend in the academic performance of each student in various subjects?

With prior knowledge of the student's performance in each subject, educators would like to know more about the trend of the student's performance in one or more specific subjects. However, the exact scores of different exams will be affected by the difficulty of the test paper, therefore cannot be directly compared. Hence, the system need to show the performance of students in each exam based on the class's performance.

T4. What is the impact of attendance and consumption on students' academic performance?

Many factors exert influence on students' development. In addition to academic performance, good habits also contribute to students' healthy growth and improvement. According to [1] and interviews with educators, attendance and consumption conditions affect students' academic performance as well. Traditional systems usually store these data separately. Therefore, a system that supports educators to explore the relationship between these factors and student performance is required.

T5. Can we compare the academic performance of the regular classes in different subjects? What are the characteristics of the different classes' academic performance?

The evaluation of teaching quality is important and complex. For the evaluation of the teaching performance of parallel classes, most schools generally compare the average scores, which has the following problems. First, the assessment based on the average score is accidental to some degree. Second, the average score cannot reflect the variation of achievements [19]. A system that could observe the latest examination results of different classes spontaneously would be of great help. What's more, the query functionality of specific classes' score distribution is required in the system to offer customized exploration.

T6. What are the preferences of students of different genders and classes when choosing subjects?

Another question educators are interested in is whether there is a gender pattern or some other patterns in each elective program. Students' subject preferences to some extent can reflect the problems in teaching and optimize the teaching scheme. For example, very few students in each class choose technology. It can be assumed that lower grades students lack an introduction to the technical subject. Schools can organize more relevant lectures and activities to increase students' interest in learning technology.

### 3.2. Design Maxims

Since the system is designed especially for educators, several major design maxims are identified from interviews and end users' feedback.

R1. Simple visual design. According to [20], educators prefer a simple visual view, which enables them to quickly understand the basic meaning and make decisions. This fact has also been affirmed by our interviewees.

R2. Hierarchical information display. Since it is impossible to display all the information at once, we are committed to design an easy-to-use visual interface while providing users with interactive operations to view detailed information. Therefore, we adopt the concept and layout of "overview first, details on command" [21].

R3. Consistent visual coding. According to the theory of object constancy and change blindness, sudden changes in the visual design should be avoided [22]. Using a consistent color scheme and view design can improve the user experience.

## 4. Assessment System of Student Learning Status

### 4.1. Determine the Student Personal Learning Assessment System

The assessment system is a whole composed of a series of interrelated evaluation criteria, which should not only play the role of inspection and incentive but also stay easy to implement. Through regression analysis of the attendance data and score data, we can find that the proportion of students with high scores is negatively correlated with the number of absences, while the proportion of students with low scores is positively correlated with that. Given that, the attendance criterion is included in the model. Since primary and middle school students are not fully developed in physical and mental aspects, they are short of self-control over the use of money. To some extent, excess consumption can reflect students' state change. More attention should be paid to the abnormal consumption records of students. Therefore, the consumption criterion is also included into the student's personal academic evaluation system. Furthermore, for score is difficult to effectively assess the efforts of students with different foundation in the learning process, this paper also introduces a criterion of progress degree. The measurement of progress is as follows:

1) Convert the original points to  $T$  standard points and describe the relative position of the students' original points in the class. The specific conversion method is

$$T = 50 + \frac{x - \bar{x}}{s} \quad (1)$$

where  $x$  is the student's score,  $\bar{x}$  is the average scores of the whole grade in this exam and  $s$  is the standard deviation of the scores of the whole grade.

2) Use regression analysis to fit the Hale index evaluation method, which determines the weights for the progress degree by the exponential equation. It can reduce the worries of students whose original level is good but worried that their effort will not be reflected by a small increase of scores. Even if there is a difference in the increase in the  $T$  standard scores, the increase in progress scores may be the same [23]. The specific calculation method is

$$y = 0.9966 \times 1.0473^t \quad (2)$$

where  $y$  is the score of progress and  $t$  is  $T$  standard point. Finally, the calculation method of a student's progress in the  $i$ -th exam is

$$\Delta y = y_i - y_{i-1} \quad (3)$$

where  $\Delta y$  is points for progress,  $y_i$  is the score for the  $i$ -th exam progress and  $y_{i-1}$  is the score for the  $(i-1)$ -th exam progress.

### 4.2. Using AHP to Determine Index Weights

Each criterion plays a different role in the student personal learning assessment system and has different importance. Since the weightings of criteria have a great influence on the assessment results,

it is essential to use appropriate and scientific methods to determine them. AHP is a combination of subjective and objective weighting method, which is more scientific than subjective or objective weighting [24]. The specific steps of AHP are as follows:

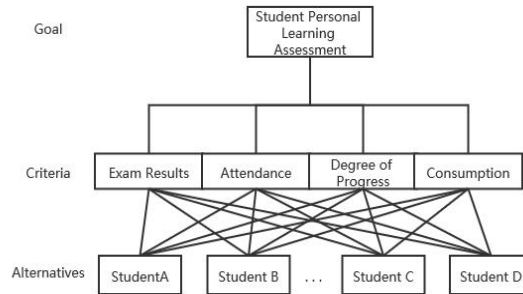


Figure 2: Student personal learning assessment model.

1) Based on the analysis in Section IV, construct the AHP hierarchical structure model of student personal learning, as shown in Figure 2.

2) Invite 36 education related workers (22 female and 14 male) to implement judgments. And construct a judgment matrix by comparing the criteria according to the 9-level scale as shown in Table 1 below.

3) Check the consistency and use the arithmetic average to calculate the weights of the criteria, as shown in Table 2.

Table 1: The fundamental scale.

Intensity of importance of an absolute scale	Definitions	Explanation
1	Equal importance	Two activities contribute equally to objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another
2,4,6,8	Intermediate value between the two adjacent judgment	When compromise is needed
Reciprocals	If activity i has one of the above numbers assigned to it when compared with activity j, the j has the reciprocal value when compared with i	



Table 2: Weights of each criterion.

Criteria	Score	Attendance	Degree of progress	Consumption
Weights	0.3	0.3	0.3	0.1

### 4.3. Calculate the Score of Student Personal Learning Assessment

According to the weight and criterion measurement method mentioned above, the calculation method of student personal learning assessment is

$$F = w_1 \times score + w_2 \times attendance + w_3 \times \Delta y + w_4 \times consumption \quad (4)$$

where  $w_1, w_2, w_3$  and  $w_4$  are respectively the weight of test score, weight of attendance, weight of progress degree.

## 5. Visualization Design

### 5.1. System Overview

Aiming at the analysis tasks mentioned in Section III, this paper designs a visual analytics system based on data in traditional teaching environment, which mainly includes three-view interfaces that are individual student portrait, class subject portrait and subject portrait.

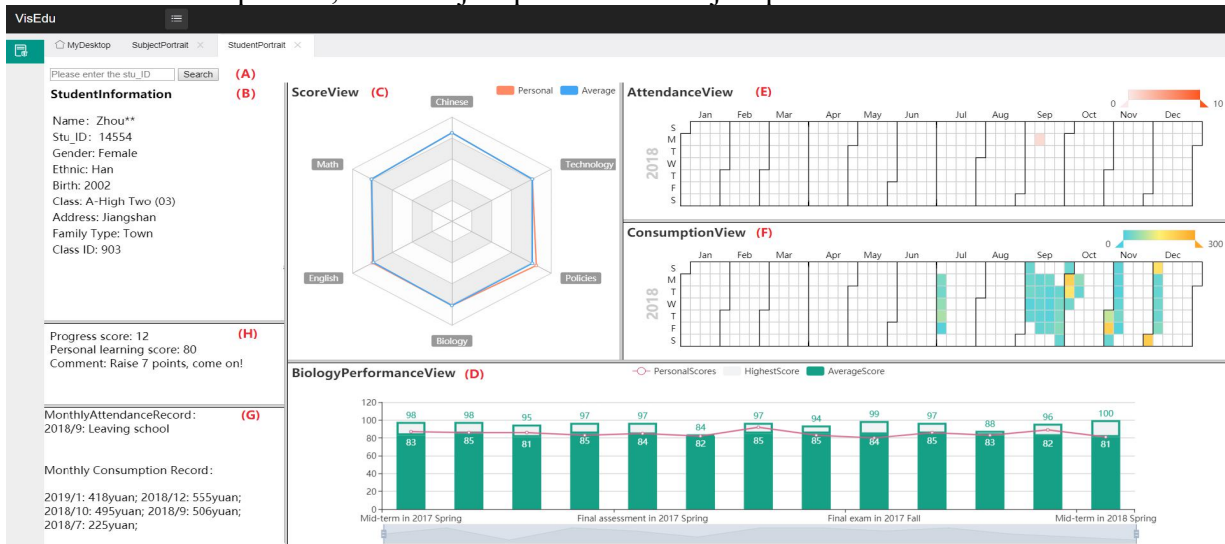


Figure 3: Student portrait.

### 5.2. Student Scale: Student Portrait Design

As shown in Figure 3, enter the student ID in the search box (A), then the left text field (B) will display the basic information of the student, including the name, student ID, name, ethnicity, etc.



(T1). We employ radar charts (C) to discover students' learning level of each subject. The axis encodes the type of subject. The red line represents the latest test scores for all subjects of the student and the blue line represents the average class score in the corresponding exam. It can intuitively reflect whether the student has a partial branch (T2) through the comparison. Since different exam difficulty results in inconsistent meaning of absolute score, the student's score is compared with the average class score and the highest class score at the same time. The users can freely click the subject label in the graph (C) which they are interested in, and then the details of student's achievements will be shown in line histogram (D). The red line represents the student's achievement, the green column's height represents the average score, and the gray column's height represents the highest score (T3). Drag the gray timeline below to view the student's previous exam results of this subject. According to task (T4), calendar charts (E) (F) are simple but effective visualizations that can be used to show the student's daily attendance and consumption. The color depth encodes the amount of consumption and the number of absences. The text box (G) shows the specific text information of the absence record.

In addition, the text box (H) shows the student's personal learning assessment score to help educators judge the student's learning situation (T1). The specific calculation process can be found in Section IV.



Figure 4: Class portrait.

### 5.3. Class Scale: Class Portrait Design

As shown in Figure 4, the selection box (A) and selection area (B) can be used to filter the score records to the first grade and subject to be analyzed. The pixel map (C) shows the latest 4 exams of the specified subjects in all classes as required by task (T6). The color encodes the average score of the class. On the one hand, the comparison of each regular class's previous scores can be observed from a horizontal perspective. On the other hand, the variation of each class's previous performance on certain subjects can be clearly seen from a vertical perspective. Since the average scores of the whole class are susceptible to extreme data, users can click on specific pixel blocks in (C) to select tests they are interested in and the details will be shown in graph (D). Graph (D) indicate the characteristics of the class's academic performance, including the gender distribution of class performance.

## 5.4. Subject Scale: Subject Portrait Design

Parallel coordinates are one of the most commonly used high-dimensional data visualization methods. According to task (T6), we use the parallel coordinate graph (A) to show the number of students choosing different subject selection plan. As shown in Figure 5 the first three axes in the parallel coordinates encode the three subjects to be selected and the last axis encodes the number of students who select this plan. Each line encodes a subject selection plan. Users can freely click the subject labels on the first three axes to select the subject option while other lines will be displayed in light green to highlight the selected polyline. Furthermore, we also use pictogram (B) to show gender distribution and two-way bar graph (C) to show the class distribution. A force-directed graph (D) is used to show the relationship between different subjects. Line segments are used to connect the disciplines related to the elective program. The size of the subject circle encodes the number of people who have chosen this subject. The thickness of the line between the two disciplines encodes the number of students who have chosen this combination. When users hover over a certain subject, other related subjects will be highlighted.

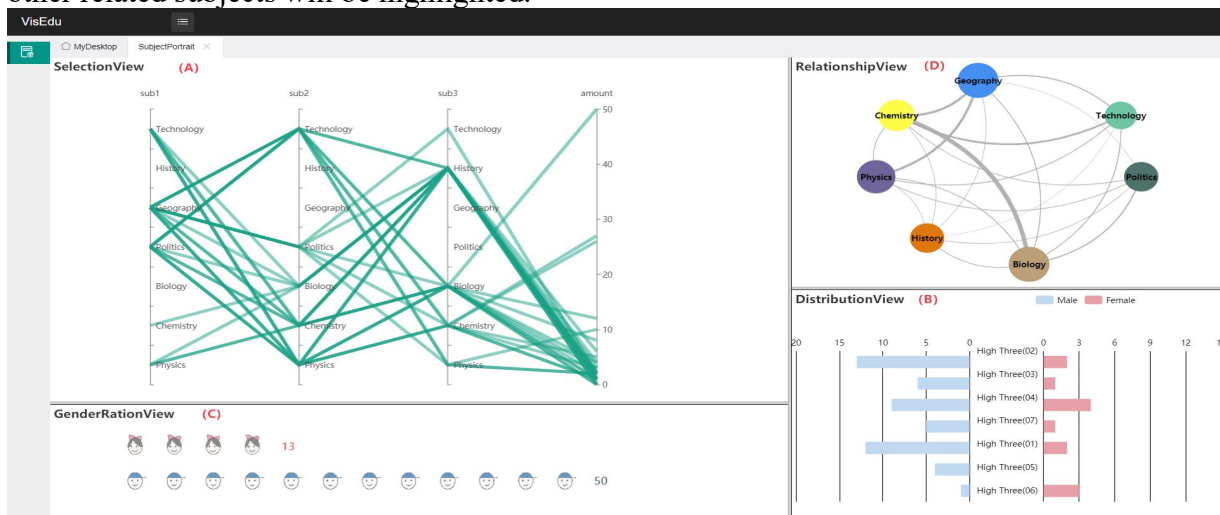


Figure 5: Subject portrait.

## 6. Case Study

The data set we used is from Ningbo Xiaoshi middle school. We invite three instructors (2 females and 1 male), who teaching in middle school and have an empirical understanding of students' learning, to use this system to analyze the student's individual learning situation, class scores and students' preference for subject selection. The conclusions were approved by three instructors, which verified the effectiveness and usability of the system.

### 6.1. Analysis of Students' Learning Situation

As shown in Figure 6, entering the student portrait interface, we can choose the student to be analyzed by entering the student number "14538" in the selection box. The information in the left text box can help users learn about the student's basic information and recent status immediately.

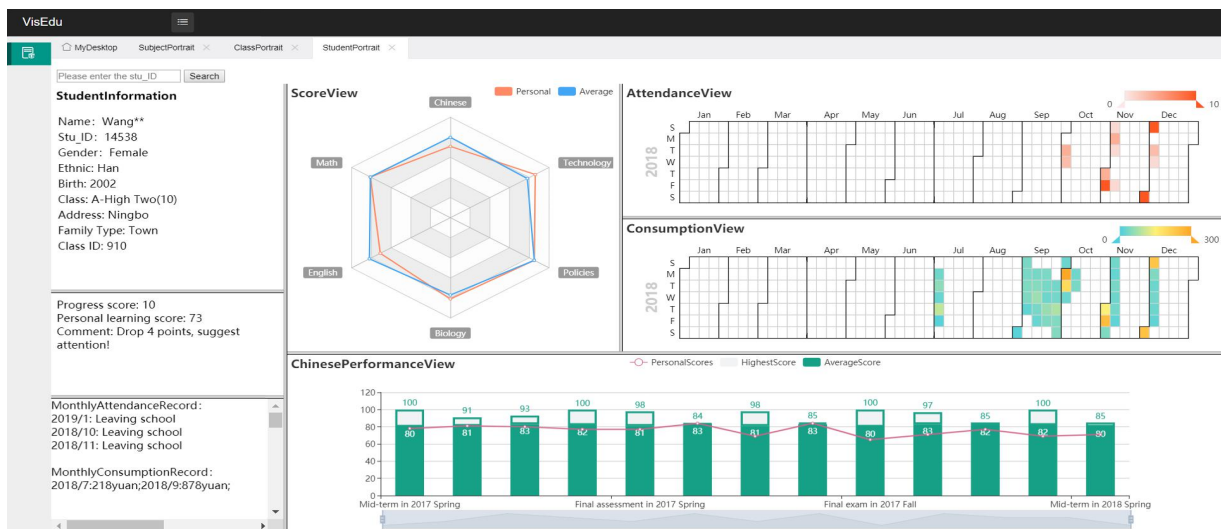


Figure 6: Student personal learning assessment.

An evident observation is that the student experienced a decline in learning status according to the learning situation assessment column. From ScoreView, we can see that the student's physics and geography scores are higher than the class's average scores, but his English and Chinese scores are below average by comparing the red personal score line and the blue class average score line. This phenomenon indicates that this student is better at mathematics and physics than humanities and social sciences. However, one test score may not reflect the student's overall learning situation. Click on the label of the Chinese subject, from ChinesePerformanceView, we can see the student's previous Chinese test scores. The red personal score line is repeatedly lower than the green column height. That is to say, the student's Chinese scores have been lower than the class average level for many times, showing that this student does have learning difficulties in Chinese. Therefore, we suggest the educators to add the student into the Chinese performance assistance program.

In order to explore the reasons for the decline of the student's scores, we analyze the AttendanceView and ConsumptionView. From the diagrams, we can see the student's consumption was relatively intensive in September, but the total amount is not high. Records with higher amounts appeared in October, November and December and there was a certain similarity with the absence record. Thus we speculate that this student might be absent from school during this period and suggest educators to pay attention to this situation. In interviews with instructors, we verified that the reality is consistent with our analysis. They also thought that abnormal attendance and consumption should be promptly paid attention to, since adolescents are at an immature stage and they have weak self-restraint.

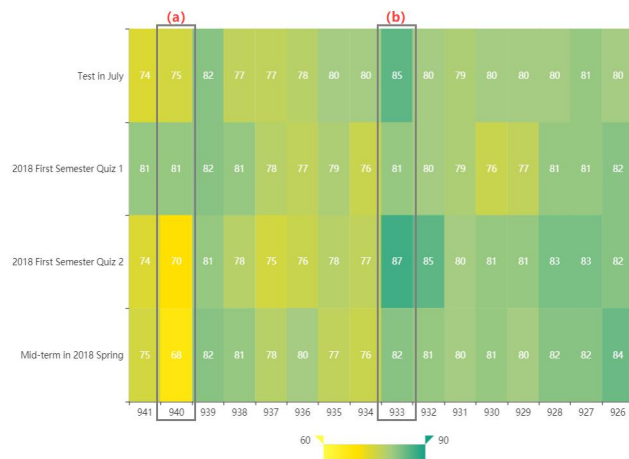


Figure 7: Analysis of class's scores.

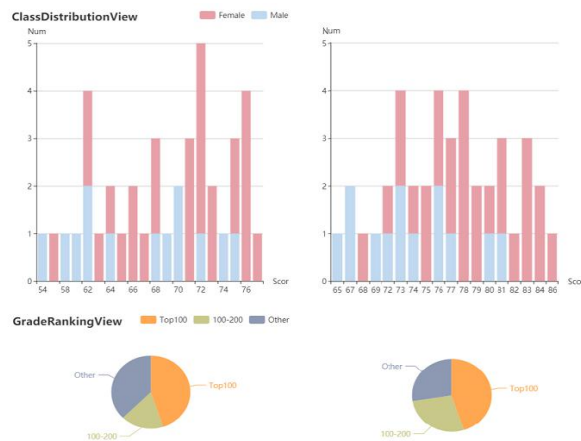


Figure 8: The comparison between class 933's Test in July and 2018 First Semester Quiz2.

## 6.2. Analysis of Regular Classes' Academic Conditions

A common task that instructors are usually interested in is to compare the academic performance of regular classes. As shown in Figure 7, entering the interface of class portrait, we choose the grade "Grade Ten", and the subject "Chinese" as our analysis goals. From GradeView, we can see the average score of each class in the last four exams. The average scores can indicate the overall learning situation of students in the same class. Through the observation from the horizontal and vertical directions, it can be found that the class 933 (Figure 7(b)) has the highest and most stable overall scores, and the 940 (Figure 7(a)) are worrying, showing a downward trend. Therefore, the educators of these two classes can communicate with each other and adjust teaching strategies to improve grades.

Since the comparison result can easily be influenced by the extreme data using class averages, we can click on the pixel block of class 933 in Test in July and 2018 First Semester Quiz 2 to explore the details of the class learning situation. The interfaces are shown in Figure 8. From ClassDistributionView, we can see more people stay in the high and middle segments and fewer people remain in the lower segments from the distribution chart on the right. In addition to analyzing the internal characteristics of the class group, it is also necessary to compare the class with other

classes. From GradeRankingView, we can find that nearly half of the students are in the top 100 and in the latest exam, the number of classmates in the 100-200 class increased. The class's Chinese score is outstanding. However, comparing the distribution of boys and girls in the two exams, we can see that both boys and girls have made progress, but the scores of girls are higher than those of boys. One instructor commended that, "In adolescence, the language learning abilities of girls are slightly higher than those of boys."

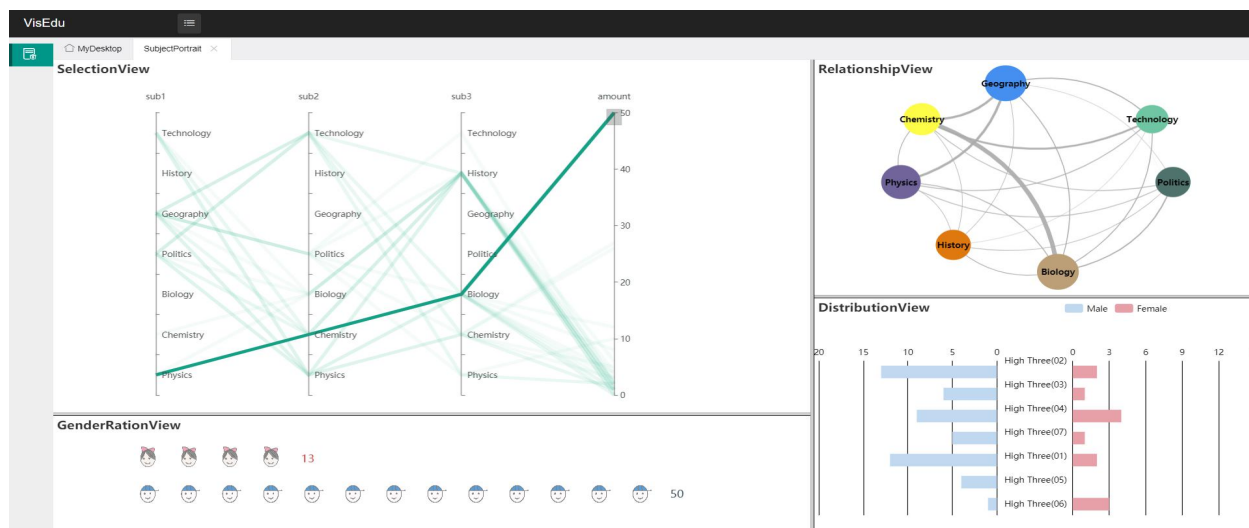


Figure 9: The analysis of student preferences for subject selection.

### 6.3. Analysis of Student Preferences for Subject Selection

One highlight of interface in Figure 9 is using a clear diagram to visualize the popular subject selection plan according to the new college entrance examination reform. Enter the subject selection program analysis interface and select the uppermost area on the fourth axis, then the program with the largest number of subject selections is highlighted, which consists of physics, chemistry, and biology. The rest of the elective programs are only selected by about 10 people which is far lower than the plan. From GenderRationView and DistributionView, we can see that the amount of students who choose this plan in each class is about the same, but the number of boys is far more than that of girls. It is speculated that in the lower grades, girls may have some difficulties in learning physics, chemistry and biology. Educators could consider organizing activities, such as physical and chemical competitions for girls and encourage them to actively develop their mathematical and physical thinking. Instructors mentioned that there are indeed large differences between boys and girls in the choice of subjects. However, students should be guided to realize that humanistic literacy and scientific literacy are the two pillars of future development. They should learn both of them well so that they can display their talents on the basis of comprehensive development.

The number of subjects selected reflects the degree of students' understanding and mastery of the subject to a certain extent. The preference of different subject combinations provides new perspectives for the optimization of instructional design. From RelationshipView, we can see that the traditional science collocation (physics, chemistry, biology) is still popular, while the traditional liberal arts collocation (politics, history, geography) are selected by a relatively small number of people. What's more, students are inclined to choose geographical subjects with two traditional science subjects.

As shown in Figure 10, the number of students who choose geography and biology is large, while that of technical and historical is small. However, taking technology as an example, under the trend of Internet in the new century, it is undoubtedly beneficial for students to establish and develop Internet thinking as soon as possible. We advise educators to carry out some activities related to informatics to increase students' interest.

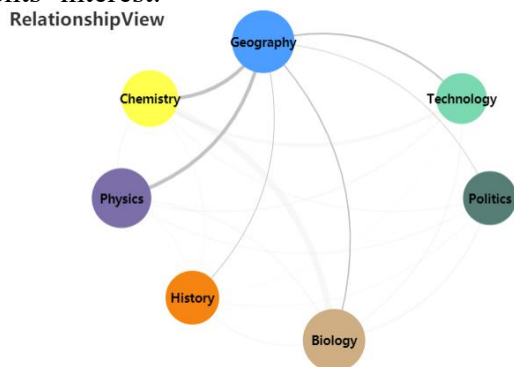


Figure 10: The analysis of student preferences for subject selection.

## 7. Conclusion and Future Work

This paper presents VisEdu, an interactive visual analytics system that helps educators to mine education data and adjust the teaching strategy according to the analysis. We described the key views of VisEdu, including (a) student scale, (b) class scale and (c) subject scale to present students' learning status and subject interest. Various interaction techniques are employed, such as filtering, searching and highlighting. In particular, in order to assist educators in a comprehensive and objective evaluation of students' learning status, this paper proposes a student personal learning assessment model based on AHP which also incorporates progress criterion into the evaluation system. The effectiveness of the system was demonstrated through case studies and expert interviews.

While the initial results are promising, there is still room for improvement in the future. Due to the lack of data, more detailed analysis cannot be made on the evaluation criteria of students' individual learning conditions, such as arts and sports activities and competitions, social practice activities, reward and punishment records, etc. In the future, we hope to collect more relevant data and improve the assessment system.

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