EVALUATING THE EFFECTS OF BKT-LSTM ON STUDENTS' LEARNING PERFORMANCE

by

Jianyao Li

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THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF COMMITTEE APPROVAL

Dr. Dominic Kao, Chair

Department of Computer and Information Technology

Dr. Baijian Yang

Department of Computer and Information Technology

Dr. Alejandra J. Magana

Department of Computer and Information Technology

Approved by:

Dr. John A. Springer

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ABBREVIATIONS

AI	Artificial Intelligence
ITS	Intelligent Tutoring System
STEM	Science, Technology, Engineering, and Mathematics
MOOCs	Massive Open Online Courses
DNN	Deep Neural Network
SVM	Support Vector Machine
KT	Knowledge Tracing
BKT	Bayesian Knowledge Tracing
DKT	Deep Knowledge Tracing
DSC	Dynamic Student Classification
RNN	Recurrent Neural Network
LSTM	Long short-term memory
PD	Problem Difficulty
MAR	Missing at Random
KNN	K-Nearest Neighbors

ABSTRACT

Today, machine learning models and Deep Neural Networks (DNNs) are prevalent in various areas. Also, educational Artificial Intelligence (AI) is drawing increasing attention with the rapid development of online learning platforms. Researchers explore different types of educational AI to improve students' learning performance and experience in online classes. Educational AIs can be categorized into "interactive" and "predictive." Interactive AIs answer simple course questions for students, such as the due day of homework and the final project's minimum page requirement. Predictive educational AIs play a role in predicting students' learning states. Instructors can adjust the learning content based on the students' learning states.

However, most AIs are not evaluated in an actual class setting. Therefore, we want to evaluate the effects of a state-of-the-art educational AI model, BKT (Bayesian Knowledge Tracing)-LSTM(Long Short-Term Memory), on students' learning performance in an actual class setting. Data came from the course CNIT 25501, a large introductory Java programming class at Purdue University. Participants were randomly separated into the control and experimental groups (AI-group). Weekly quizzes measured participants' learning performance. Pre-quiz and base quizzes estimated participants' prior knowledge levels. Using BKT-LSTM, participants in the experimental group had questions from the knowledge that they were most lacking. However, participants in the control group had questions from randomly picked knowledge. The results suggested that both the experimental and control groups had lower scores in review quizzes than in base quizzes. However, the score difference between base quizzes and review quizzes for the experimental group was more often significantly different (three quizzes) compared to the control group (two quizzes), demonstrating the predictive capability of BKT-LSTM to some extent. Initially, we expected that BKT-LSTM would enhance students' learning performance. However, in post-quiz, participants in the control group had significantly higher scores than those in the experimental group. The result suggested that continuous complex questions may negatively affect students' learning initiatives. On the contrary, relatively easy questions may improve their learning initiatives.

1. INTRODUCTION

1.1 Background

Research demonstrates that student performs better when the learning content is personalized [1]. Also, cognitive theory suggests students actively obtain rather than being passively given knowledge [2]. Hence, personalized learning content would be an effective method of enhancing students' learning outcomes. However, it is unrealistic for instructors to have the learning content personalized for every student since the number of students is far more than that of instructors. To tackle the deficiency, adapting course materials through strategies or models would be a good choice. In the early stages, personalized learning content was generated by simple technologies like arranging course materials or pieces of knowledge in a personalized order by setting a learning goal [3]. Researchers also considered providing necessary problem solution assistance to students [4]. Indeed, such ideas were innovative at that time, describing a preliminary Intelligent Tutoring System (ITS). It succeeded in assisting instructors and improving students' learning experience in the early years. However, the early ITS is still far from being satisfactory for learning content adapting [5]. The early ITS did not perform well when applying to the class setting since the personalized strategies did not fully utilize students' features. For instance, curriculum sequencing provides students with the best learning paths based on their learning goals. However, other features like prior knowledge, age, major are not included in curriculum sequencing. To this end, machine learning models and Deep Neural Networks (DNNs) would be helpful.

Today, as online courses become increasingly prevalent due to their accessibility and convenience, the demands for high-quality and personalized learning also grow faster and faster. Meanwhile, machine learning theories and DNNs provide a new possibility for further improving ITS' s performance. Classic machine learning models, such as random forests, Logistic Regression (LR), Support Vector Machine (SVM), are widely applied in many areas. The retail industry uses machine learning models for predicting consumers' shopping behaviors. Manufacturing adjusts the parameters of products based on machine learning models to promote yield rate. Insurance companies utilize logistic regression and random forests to predict clients' purchase probability. Also, educational data mining is promising on pre-

dicting students' learning outcomes, providing information for instructors to revise teaching strategies [6]. Rather than training models on students one by one, it would be better to assign students to different groups. Adaptive collaboration support serves to divide students into different groups according to their knowledge level [7]. Adaptive collaboration support offers opportunities for students having similar knowledge levels to help each other. In addition, over recent years, massive open online courses (MOOCs) have become increasingly prevalent. Though solving problem in time is essential during the learning, it is difficult for instructors to answer students' questions timely. Researchers attempt to develop a virtual instructor through Natural Language Processing (NLP) to handle massive questions from students. The virtual instructor is a type of interactive educational AIs. It improves the interaction frequency between students and instructors [8], [9]. Moreover, the model should generate a new state from the previous state since students' learning states keep changing as they continue obtaining knowledge. The objective can be achieved by using a state-of-the-art DNN called Long Short-Term Memory (LSTM), which adequately learns students' behaviors in a time series. Research demonstrates that LSTM outperforms the majority of classic machine learning models in terms of predictive analysis. LSTM successfully predicts students' clicking frequencies towards certain learning content and current question's success rate [10]. However, researchers only fitted models to the existing dataset rather than the data collected from actual classes. Though educational AIs have drawn more and more attention, it turns out that educational AIs fall far behind the retail industry, information technology companies, and finance [11]. On the other hand, the rapid development of online learning platforms generates a huge demand for high-quality courses and better learning experiences. Therefore, we need to dive deeper into educational AIs and explore their effects on students' learning.

1.2 Motivation

Based on the above background, several problems exist in the development of educational AIs. First, the educational technologies are still not satisfactory. Besides, the number of research on educational AIs is limited, which does not satisfy the demands of online

learning platforms. Indeed, researchers proposed well-performed educational AIs. However, the models only fit the existing dataset rather than collecting data from a real class setting. Therefore, this study aimed to develop a well-performed educational AI and evaluated if the AI affects students' learning performance. Students' engagement (perceived engagement) was also studied, but the study was included in [12], not in the current thesis.

1.3 Research Question

Based on the discussion and findings above, our research question would be: **can educational AI enhance students' learning performance?** To narrow down the research scope, the educational AI used in this study is a state-of-the-art knowledge tracing model called BKT-LSTM. Weekly quizzes will measure students' learning performance in the experiment, and we will recruit participants in a Java programming course. Hence, the research question becomes **can integrating BKT-LSTM into weekly quizzes enhance students' learning performance in programming?**

2. REVIEW OF LITERATURE

This section will examine the learning theories and the measurement of students' learning performance. Besides, this section discusses the pros and cons of the state-of-the-art predictive educational AI models, including Bayesian Knowledge Tracing (BKT), Deep Knowledge Tracing (DKT), and Long Short-Term Memory (LSTM).

2.1 Learning performance

This study aims to evaluate the effects of BKT-LSTM, a predictive educational AI, on students' learning performance. However, learning performance is an abstract concept; quantifying students' learning performance requires a specific methodology. Students' learning performance (outcomes) are usually measured by "criterion tests" or "knowledge tests," which contain multiple-choice questions [13]–[16]. The learning performance measured by tests reflects the "objective learning performance" of students, indicating students' knowledge acquirement during the learning. This learning performance is often used in evaluating the performance of predictive educational AIs. On the other hand, students' learning performance can also be measured by scales or questionnaires. This learning performance reflects students' subjective judgment of their changes on the learning acquirement. "subjective learning performance" is self-reported by students, measured by scales or questionnaires [17]–[21], and it is appropriate for estimating the effects of interactive educational AIs (like Jill Watson [8]) on students' engagement. The model BKT-LSTM is a predictive educational AI requiring objective learning data from students. Therefore, in this study, knowledge tests are more appropriate for measuring students' learning performance.

2.2 Learning theories

As mentioned in the introduction, students perform better under personalized learning content, which is consistent with the cognitive theory that students actively obtain rather than being passively given knowledge [1], [2]. Researches also suggested that "formative feedback" can enhance students' learning performance . Defined by Shute, "formative feed-

back" is the information that aims to modify students' behaviors or to think to enhance their learning performance [22]. For example, the exam materials that test students' acquisition of specific pieces of knowledge can be "formative feedback". In this study, we used weekly quizzes as "formative feedback" and assumed those materials could enhance students' learning performance. Therefore, using BKT-LSTM to generate personalized learning content for students might enhance their learning performance to some extent.

2.3 Bayesian Knowledge Tracing (BKT)

Students' learning states would change (e.g., from "unlearned" to "learned") as they continue to obtain knowledge during the course. Knowledge Tracing can model the learning transition [23]. KT assumes students' learning states are either "learned" or "unlearned" and predicts students' learning states towards a specific piece of knowledge through the four below parameters: $P(L_0)$, $P(T)$, $P(G)$, and $P(S)$. Once we calculate the four parameters

Table 2.1. Parameters for Bayesian knowledge tracing

Parameters	**Meanings**	**Remarks**
$P(L_0)$	Initial Learning	The probability that a specific knowledge is learned prior to learning
$P(T)$	Acquisition	The probability that the state for a specific knowledge will transit from unlearned to learned
$P(G)$	Guess	The probability that students give correct answers in the unlearned state
$P(S)$	Slip	The probability that students give incorrect answers in the learned state

from students, we can predict students' learning states using the following equation:

$$P(L_n) = P(L_{n-1}|evidence) + (1 - P(L_{n-1}|evidence)) * P(T) \tag{2.1}$$

where $P(L_n)$ is the probability that a specific piece of knowledge is learned when student tries the n_{th} attempt. $P(L_{n-1}|evidence)$ is the probability that the knowledge has been learned based on the evidence (whether the answer is correct or not).

Applying the above equations, $P(L_n)$ relates to the previous learning state if the knowledge has been learned plus the probability that knowledge transits to the learned state if it is not learned. Evidence depends on the correctness of answers. Bayesian inference can be applied to calculate $P(L_{n-1}|evidence)$. However, KT has several drawbacks though it has a satisfactory performance in predicting students' learning states. For example, KT assumes students will not forget the knowledge once it is learned, which is inconsistent with the actual situation. Besides, KT holds that the acquisition probability of a piece of specific knowledge is independent of other knowledge, i.e., learning transfer is not considered. However, the acquisition of a specific piece of knowledge may affect the acquisition of the other in actual learning. The KT model implements Bayesian Knowledge Tracing (BKT) since it uses Bayesian inference to predict student performance. However, it only utilizes the simplest assumptions and knowledge-related parameters (probabilities). Researchers demonstrate that BKT performance can be enhanced by adding student-specific parameters [24].

2.4 Deep Knowledge Tracing (DKT)

Corbett et al. provided a solution to model students' learning states by Bayesian inference. It showed effectiveness in predicting student performance towards specific pieces of knowledge. Piech et al. suggested that a DNN called Recurrent Neural Network (RNN) can better model the learning process. Based on RNN, Deep Knowledge Tracing was proposed (DKT) [25]. The following equation defines RNN:

$$\mathbf{h}_t = tanh(\mathbf{W}_{hx}\mathbf{x}_t + \mathbf{W}_{hh}\mathbf{h}_{t-1} + \mathbf{b}_h), \tag{2.2}$$

$$\mathbf{y}_t = \sigma(\mathbf{W}_{yh}\mathbf{h}_t + \mathbf{b}_y). \tag{2.3}$$

where $\mathbf{x}_t$ is a one-hot encoding vector of students' interaction and $\mathbf{y}_t$ is the predicted vector for students; $\mathbf{W}_{hx}, \mathbf{W}_{hh}, \mathbf{W}_{hy}$ is input weight matrix, recurrent weight matrix, and output weight matrix, respectively. $\mathbf{b}_h$ is latent bias and $\mathbf{b}_y$ is output bias. $\mathbf{h}_0$ is the initial state.

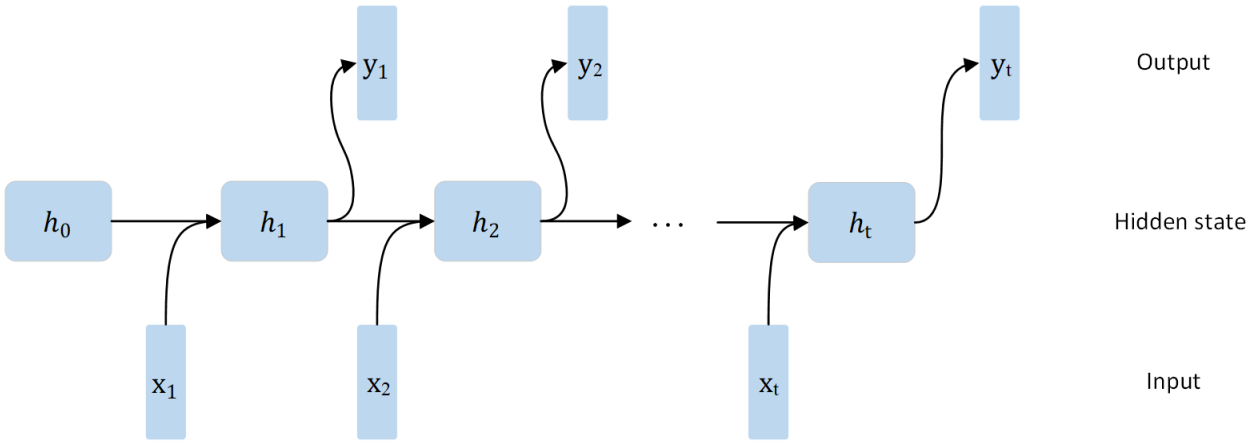


Figure 2.1. DKT architecture

In practice, $\mathbf{x}_t = \{k_t, r_t\}$ stands for students' correctness of a specific piece of knowledge at time t (k_t is the knowledge, r_t is the correctness). $\mathbf{y}_t = \{k_{t+1}, r_{t+1}\}$ is the prediction of students' correctness at time $t+1$. DKT does not require complicated feature scaling, and it only needs to vectorize students' correctness of pieces of knowledge. DKT is a more promising knowledge tracing model, and it can utilize the features that BKT cannot fully use [26]. However, DKT may have gradient exploding and vanishing problems, given that it is established on RNN. In other words, DKT cannot tackle long sequence learning. Long-Short Term Memory (LSTM) uses several gates (forget gate, input gate, output gate) to control the input and output sequence, thereby solving the gradient issue to some extent. Therefore, the LSTM-based DKT model would be more appropriate for long sequence learning than that of the RNN-based DKT model [27].

2.5 DKT-DSC

DKT only considers students' knowledge mastery (whether correct or not on specific pieces of knowledge) though it is effective in predicting students' performance. However, peer ability can positively affect students' learning achievement [28]. Therefore, including student ability into DKT would be a possible improvement. To this end, Minn et al. proposed an improved DKT model called Deep Knowledge Tracing and Dynamic Student Classification (DKT-DSC) by taking students' learning ability into account [29]. In DKT-DSC, K-means clustering assigns students to different groups based on their learning ability, shown in Figure 2.2. After that, LSTM predicts the learning performance of each group at different time intervals (each time interval is a cluster), shown in Figure 2.3. DKT-DSC improves the

Knowledge ID	10001	10002	10003	10004	10005	10006	10007	10008	10009	10010
Correctness	0	0	1	0	0	1	1	0	1	1

Time Interval 1 | Time Interval 2 | Time Interval 3

Figure 2.2. Time interval of a student's attempt sequence

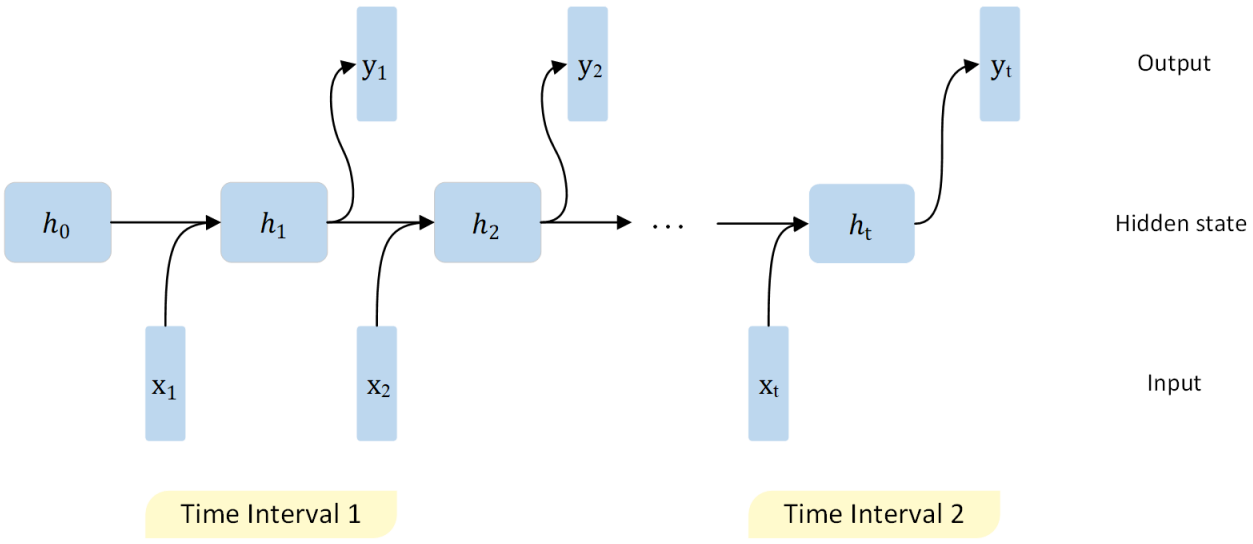


Figure 2.3. DKT-DSC architecture: comparing to standard DKT, DKT-DSC relates to each time interval (cluster)

standard DKT model by adding a student ability module. However, the cluster number for K-means clustering is essential. It might require a long time parameter tuning since it

is difficult to determine a reasonable cluster number for student ability. More calculation details will be discussed in the methodology section.

2.6 BKT-LSTM

Based on DSC-DKT, BKT-LSTM [30] introduces three features: individual knowledge mastery, ability profile, and problem difficulty. Problem difficulty contributes to the prediction of learning performance [31]. In BKT-LSTM, the three calculated features will be passed to LSTM. After that, LSTM outputs the acquirement possibilities of students' learning mastery on pieces of knowledge. The BKT-LSTM model is defined as the following:

$$\mathbf{h}_t = tanh(\mathbf{W}_{hx}[f_t] + \mathbf{W}_{hh}\mathbf{h}_{t-1} + \mathbf{b}_h), \tag{2.4}$$

$$\mathbf{y}_t = \sigma(\mathbf{W}_{yh}\mathbf{h}_t + \mathbf{b}_y). \tag{2.5}$$

where $[f_t] = \{P(k_t), ab_z, PD(P_\text{j})\}$. $P(k_t)$, ab_z and $PD(P_\text{j})$ is knowledge mastery, ability profile, and problem difficulty, respectively; $\mathbf{y}_t$ is the predicted vector for students; $\mathbf{W}_{hx}$, $\mathbf{W}_{hh}$, and $\mathbf{W}_{hy}$ represents input weight matrix, recurrent weight matrix, and output weight matrix, respectively.

Different from the standard DKT, the input vector x_t becomes $[f_t] = \{P(k_t), ab_z, PD(P_\text{j})\}$. $P(k_t)$ is the assessment for students' knowledge mastery at time t; ab_z represents students' ability profile (the correctness or probability towards problems) at time interval z; $PD(P_\text{j})$ stands for the difficulty of problem P_j at time t. BKT-LSTM leverages more features from students, and it outperforms the standard DKT and DKT-DSC on the dataset ASSISTment 2009-2010 (skill builder) and ASSISTment 2014-2015. The ASSITment dataset was collected through a computer-based learning system. The system collects data from students as they do exercises on it. ASSISTment dataset is popular in estimating the performance of knowledge tracing models. However, most knowledge tracing models are not evaluated under a real class setting though they perform well under the ASSISTment dataset. The results on the existing dataset do not reflect the models that can affect students' learning performance.

Consequently, rather than staying at a theoretical level, experiments are required to evaluate the effects of BKT-LSTM on students' learning performance.

3. METHODOLOGY

This section elaborates on the components of the BKT-LSTM model [30] and the corresponding definitions and calculations. Besides the components of BKT-LSTM, data source and data collection for BKT-LSTM training are also discussed. Finally, an experimental design to evaluate the effects of BKT-LSTM on students' learning outcomes is given.

3.1 ASSUMPTIONS

The use of BKT-LSTM requires the following assumptions:

- We assume the learning ability of students will improve through practices rather than remaining static.
- One practice problem only relates to one piece of knowledge. However, one problem sometimes includes more than one knowledge in actual tests.
- We assume that each problem or knowledge is independently learned, i.e., acquiring a piece of knowledge will not affect the learning of other knowledge.

3.2 BKT-LSTM

BKT-LSTM takes advantage of three features from students: knowledge mastery, ability profile, and problem difficulty. After that, the three features will be passed to LSTM. LSTM will generate a probability vector for students' learning acquirement. In other words, the generated vector demonstrates how likely students have learned that knowledge.

3.2.1 Knowledge mastery

Knowledge mastery is computed by the classic BKT model with four parameters (probabilities): $P(L_0)$, $P(T)$, $P(G)$, and $P(S)$ (defined in Table 2.1). The following equations define the Bayesian inference process [23]:

$$P(L_t|1) = \frac{P(L_{t-1})(1 - P(S))}{P(L_{t-1})(1 - P(S)) + (1 - P(L_{t-1}))P(G)} \tag{3.1}$$

$$P(L_t|0) = \frac{P(L_{t-1})P(S)}{P(L_{t-1})P(S) + (1 - P(L_{t-1}))(1 - P(G))} \tag{3.2}$$

$$P(L_t) = P(L_t|Action) + (1 - P(L_t|Action))P(T) \tag{3.3}$$

$$P(C_t) = P(L_{t-1})(1 - P(S)) + (1 - P(L_{t-1}))P(G) \tag{3.4}$$

where 0, 1 denotes incorrect and correct answers for *Action*, respectively.

Depending on the answer's correctness (0 or 1), the probability $P(L_t)$ can be computed by equation 3.1 or 3.2. If students correctly answer the question, their learning states will be updated by equation 3.1. Otherwise, their learning states will be updated by equation 3.2. The probability $P(C_t)$ that students learn the knowledge after answering the question can be calculated by equation 3.4. Therefore, using the above Bayesian inference process, we have a probability vector of students' knowledge mastery for each piece of knowledge.

3.2.2 Ability profile

Students' correctness rates and K-means clustering determine their ability profiles at time interval z. Each time interval z includes several problems answering attempts. Students' ability profiles can be computed from the previous problem answering (attempts). Ability profiles describe students' abilities towards each piece of knowledge. Correctness rate for a specific piece of knowledge x_{j} at time interval $1 : z$ is defined as follows [29]:

$$R(x_{\mathrm{j}})_{1:z} = \sum_{t=1}^{z} \frac{(x_{\mathrm{j}t})}{|N_{\mathrm{j}t}|} \tag{3.5}$$

where $x_{\mathrm{j}t}$ is either 0 (incorrect) or 1 (correct), depending on the answer's correctness for the specific piece of knowledge x_{j} at time interval t; $|N_{\mathrm{j}t}|$ is the total number of attempts for knowledge x_{j} at time interval t.

Consequently, the ability profile of student i towards each piece of knowledge $d^{\mathrm{i}}_{1:z}$ is defined as [29]:

$$d^{\mathrm{i}}_{1:z} = (R(x_1)_{1:z}, R(x_2)_{1:z}, ..., R(x_n)_{1:z}) \tag{3.6}$$

where n represents the total number of problems (knowledge).

After computing the ability profile, K-means clustering assigns students into different groups at each time interval z. The ability profile of student i at a time interval from 1 to $z-1$ determines the student's group. That is, $d^{\mathrm{i}}_{1:z-1}$ determines students' group assignment. The following equation describes the K-means clustering process of students at time interval Seg_z [29]:

$$Cluster(Stu_{\mathrm{i}}, Seg_z) = \arg\min_{C} \sum_{c=1}^{K} \sum_{d^{\mathrm{i}}_{1:z-1} \in C_c} \|d^{\mathrm{i}}_{1:z-1} - \mu_c\|^2 \tag{3.7}$$

where μ_c is the mean points for cluster C_c.

3.2.3 Problem difficulty

Problem difficulty is one of the three features for students. Initially, the difficulty level, PD, of a problem, P_{j}, can be computed as follows [30]:

$$PD(P_{\mathrm{j}}) = \begin{cases} \delta(p_{\mathrm{j}}), & \mathrm{i}f \ |N_{\mathrm{j}}| \geq 4 \\ 5, & else \end{cases} \tag{3.8}$$

$$\delta(p_{\mathrm{j}}) = modulo_{10}\left(\frac{\sum_{\mathrm{i}}^{|N_{\mathrm{j}}|} O_{\mathrm{i}}(p_{\mathrm{j}})}{|N_{\mathrm{j}}|} \cdot 10\right) \tag{3.9}$$

where N_{j} is the number of students that answer the problem; $O_{\mathrm{i}}(p_{\mathrm{j}})$ is the problem answering result (either 1 or 0).

Essentially, the above problem difficulty computing method is based on the overall correctness rate. If less than four students answer a specific problem, it will be set to 5. However, considering our experiment setting, which will be discussed in the experimental

design section, which collects data from students' weekly tests, such a problem will not exist. Therefore, problem difficulty can be simplified as:

$$PD(P_{\mathrm{j}}) = modulo_{10}\left(\frac{\sum_{\mathrm{i}}^{|N_{\mathrm{j}}|} O_{\mathrm{i}}(p_{\mathrm{j}})}{|N_{\mathrm{j}}|} \cdot 10\right) \tag{3.10}$$

Problem difficulty is mapped onto a scale from 1 to 10. Ten levels would be too many for weekly test problems. Therefore, reducing the level number or exploring a more appropriate method to define the difficulty would be a future direction.

3.3 Simplified BKT-LSTM

The standard BKT-LSTM model has three features: knowledge mastery calculated by BKT, ability profile produced by K-means clustering, and problem difficulty defined in equation 3.10. However, based on the ablation study in [30], the introduction of the ability profile does not contribute to a tangible AUC result improvement (only 0.1 higher) on the ASSISTment and Algebra dataset, shown in Table 3.1. The feature combinations of BKT-LSTM is listed as follows:

- BKT-LSTM-1: skill mastery.
- BKT-LSTM-2: skill mastery and ability profile.
- BKT-LSTM-3: skill mastery and problem difficulty.
- BKT-LSTM-4: skill mastery, ability profile, and problem difficulty.

Thus, to reduce the complexity of BKT-LSTM, the calculation of ability profile will be removed in practice.

3.4 Data collection

This section discusses what data is required to train the BKT-LSTM model. For knowledge mastery, from equation 3.1 to 3.4, each piece of knowledge is independently learned by the four parameters. Applying the above Bayesian inference process, we assume that

Table 3.1. AUC result for ablation study of BKT-LSTM

Models	ASS-09	ASS-14	Algebra
BKT-LSTM-1	0.686	0.680	0.730
BKT-LSTM-2	0.720	0.701	0.743
BKT-LSTM-3	0.792	0.702	0.849
BKT-LSTM-4	0.802	0.707	0.851

a piece of knowledge does not affect the other knowledge's learning. Hence, each problem only relates to a specific piece of knowledge. The knowledge mastery module of BKT-LSTM requires **student_id**, **knowledge_id**, and **correctness**, where correctness is a binary feature that represents whether the knowledge is correctly answered or not (0 is incorrect, 1 is correct).

Problem difficulty is also considered in BKT-LSTM, which is defined by equation 3.10. Apparently, BKT-LSTM needs a problem difficulty feature called **difficulty**. Problem difficulty needs to be initialized before students start to do exercises. In other words, each problem needs to be initialized by certain values. However, the "objective problem difficulty" would not work for students. Students might have different problem difficulty even for the same problem. In other words, problem A might be difficult for student A, but it is easy for student B. Problem difficulty varies through students. In addition, problem difficulty will be updated after each time interval. Therefore, we consider applying the strategy in [29] to initialize each problem difficulty to 5 (median). In practice, problem difficulty can be computed from **problem_id** and **correctness** using equation 3.10. In sum, the training of BKT-LSTM requires five features (**student_id**, **knowledge**, **knowledge_id**, **problem_id**, **correctness**). An example is given in Table 3.2 and dataflow for BKT-LSTM is described in Figure 3.1. The feature **knowledge** only clarifies the knowledge that the problem testing. Therefore, **knowledge** will not be included in the training of BKT-LSTM.

Table 3.2. Features for BKT-LSTM training

student_id	knowledge	knowledge_id	problem_id	correctness
1001	Data	9001	2001	1
1001	Data	9001	2002	1
1002	Variables	9002	3001	0
1003	Control Flow	9003	4001	1

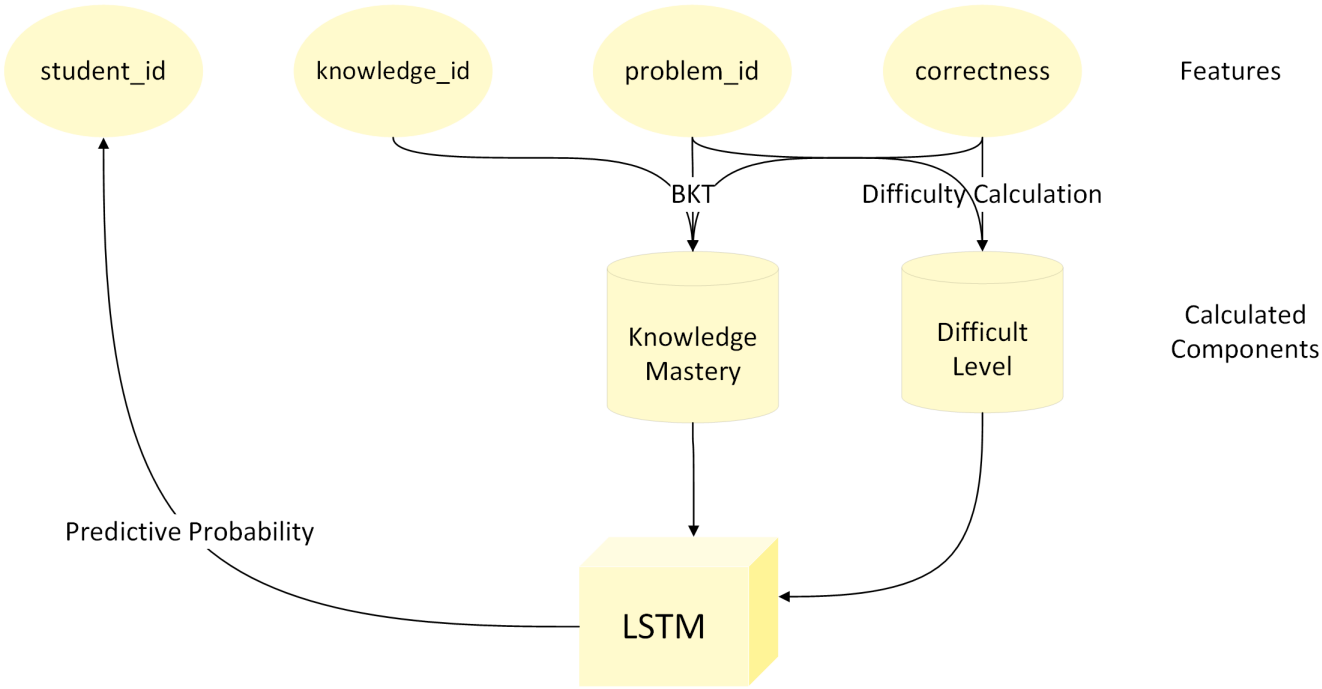


Figure 3.1. Dataflow for BKT-LSTM training

3.5 Model hyper-parameters

The simplified BKT-LSTM was implemented by TensorFlow 2.0, using 100 parallel LSTM units. The model used the default Adam (learning rate = 0.001, decay = 10e-7) as the optimizer. We did not have much data as a common training dataset in the experiment. Therefore, instead of setting the batch size to 32, we set the batch size to 1. Also, BKT-LSTM was trained for 200 epochs to reach a stable loss. To avoid over-fitting, the dropout rate was set to 0.2. Training fraction, validation fraction, and test fraction were set to 0.6, 0.2, 0.2, respectively. In the outputs of BKT-LSTM, we did not observe a large difference of AUC between the training set, validation set, and test set (less than 0.3).

3.6 Experiment design

This section describes the course CNIT 25501 and the integration of BKT-LSM into the actual class setting. Besides, the experimental design evaluates the effects of BKT-LSTM on students' learning will be given.

3.6.1 Course CNIT 25501

CNIT 25501, a large introductory class to programming, is offered by the polytechnic institute of Purdue university, introducing the basic ideas of Java programming. Data will be collected from the students that are willing to participate in our experiment in CNIT 25501. The class setting will remain the same for participants and non-participants. However, besides the regular weekly exercises, participants require taking extra quizzes every week as part of the study. Based on the calendar of CNIT 25501 in Figure 3.2, we determine to reinforce students' understanding of Variable/Data, String I/O, Control Flow, Arrays, and Classes. The above pieces of Java knowledge are the most basic but the most significant for Java beginners.

Week	Date	Topic	Date	Topic	Lab Due
1			1-20	[0] Introduction	
2	1-25	[1] Java (ch. 1, 2.1-2.3)	1-27	[2] Variables/Data (ch. 3.1-3.5)	Lab 0
3	2-01	[3] Strings I/O (ch 3.6-3.7)	2-03	[4] Control Flow (ch. 3.8)	
4	2-08	[5] Arrays 3.9-3.10	2-10	[6] Classes (ch. 4.1-4.3)	Lab 1
5	2-15	[7] Classes (ch. 4.4-4.6)	2-17	Reading Day (No Classes)	
6	2-22	[8] Classes (ch. 4.7-4.10)	2-24	[9] Multi-class Systems	Lab 2
7	3-01	[10] Inheritance (ch. 5.1)	3-03	[11] Inheritance (ch. 5.2-5.4)	
8	3-08	[12] Inheritance (ch. 5.5-5.8)	3-10	[13] Basic GUI (basic ch. 10, 12)	
9	3-15	[14] Basic Events (ch. 11.1-11.2)*	3-17	Midterm 1 Exercises	Lab 3
10	3-22	Midterm 1 Exercises	3-24	[16] Interfaces (ch. 6.1-6.2)	
11	3-29	[17] Inner Classes (ch. 6.4)	3-31	[18] Exceptions (ch. 7.1-7.2)	Lab 4
12	4-05	[19] Exceptions (ch. 7.3-7.6)	4-07	Midterm 2 Exercises	
13	4-12	Midterm 2 Exercises	4-14	Project Work	
14	4-19	Project Work	4-21	Presentations	
15	4-26	Presentations	4-28	Presentations	

Labs are due Friday at midnight.
For more details, see Lab Policies & Expectations.
*Lecture 15 will be a review lecture released prior to the Midterm 1 Exercises.

Figure 3.2. Calendar for CNIT 25501

Before the course begins, participants are required to take a pre-quiz to establish prior knowledge profiles. Pre-quiz contains demographic questions and questions from the above pieces of knowledge. As the course starts, participants need to take "base quizzes" and "review quizzes" every week to update their learning performance towards each piece of knowledge. Details will be given in the next section. In the last week (week 5), participants will have post-quizzes, including all the knowledge they have learned in the course before. The effects of BKT-LSTM on students' learning performance will be estimated through the differences between the base quizzes and the review quizzes. Therefore, including the post-quiz, five weeks are needed for running our experiment: Variables/Data in week 1, Strings I/O and Control Flow in week 2, Arrays and Classes in week 3 to 4, and post-quiz in week 5. As an encouragement, students who participate in the experiment will have up to 3% extra credits for completing all the quizzes. Participants will get 0.1% extra credit for finishing a base quiz or a review quiz to avoid skipping quizzes. Participants will have the remaining 2% extra credits if all the quizzes are completed. Figure 3.3 describes the allocation of extra credits for quizzes.

3.6.2 Qualtrics

Students will have weekly quizzes through an online survey platform called Qualtrics. Using Qualtrics, weekly quizzes can be distributed to participants through emails. Participants only need to click the links and start doing the quizzes. With that convenience, we consider conducting a remote experiment. Qualtrics will facilitate our experiment progress. Sample questions from the knowledge and Data/Variables and the user interface of Qualtrics are given in Figure 3.4.

3.6.3 Base quizzes & review quizzes

Participants and non-participants will have the same class setting and regular weekly exercises. However, participants will have "base quizzes" and "review quizzes." Base quizzes contain the knowledge of the given week, and they are the same for the control and experimental groups. Base quizzes serve to establish the learning profiles for participants. However,

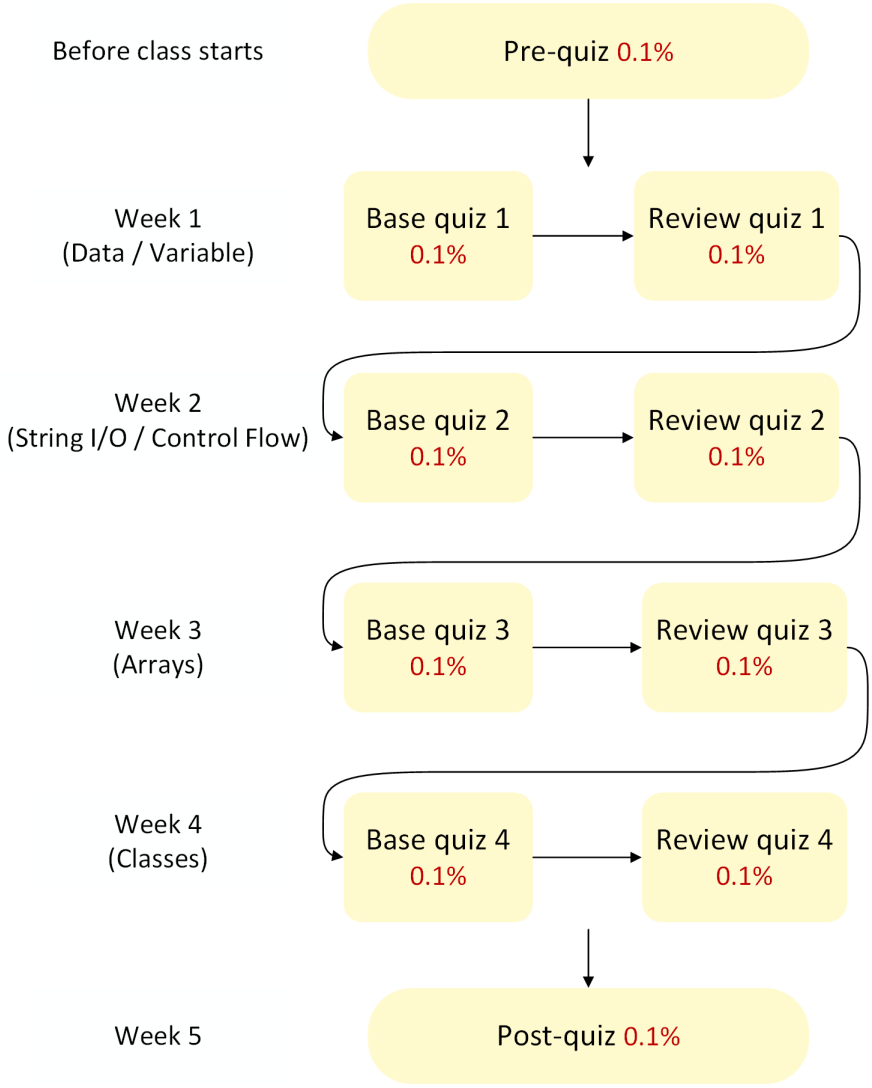


Figure 3.3. Extra quizzes and corresponding credits allocation. Participants will have 2% bonus credits for completing all the quizzes.

review quizzes may vary based on the experiment condition. Participants' questions come from a self-developed question bank. The question bank includes 140 self-developed questions and 106 adapted questions from publicly available question banks [1] [2]. The adapted questions were from Java final exams in Chinese universities. Also, all the questions were

[1]↑"JAVA programming final exam questions", [Online]. Available: https://wenku.baidu.com/view/5010c983c67da26925c52cc58bd63186bdeb9245.html [Accessed:30-Jun-2021].
[2]↑"JAVA programming final exam questions and answers", [Online]. Available: https://wenku.baidu.com/view/8c6903d48f9951e79b89680203d8ce2f006665ed.html?rec_flag=default&fr=pc_newview_relate1001_12wk_rec_doc1001_138c6903d48f9951e79b89680203d8ce2f006665ed&sxtsI624534888041 [Accessed:30-Jun-2021].

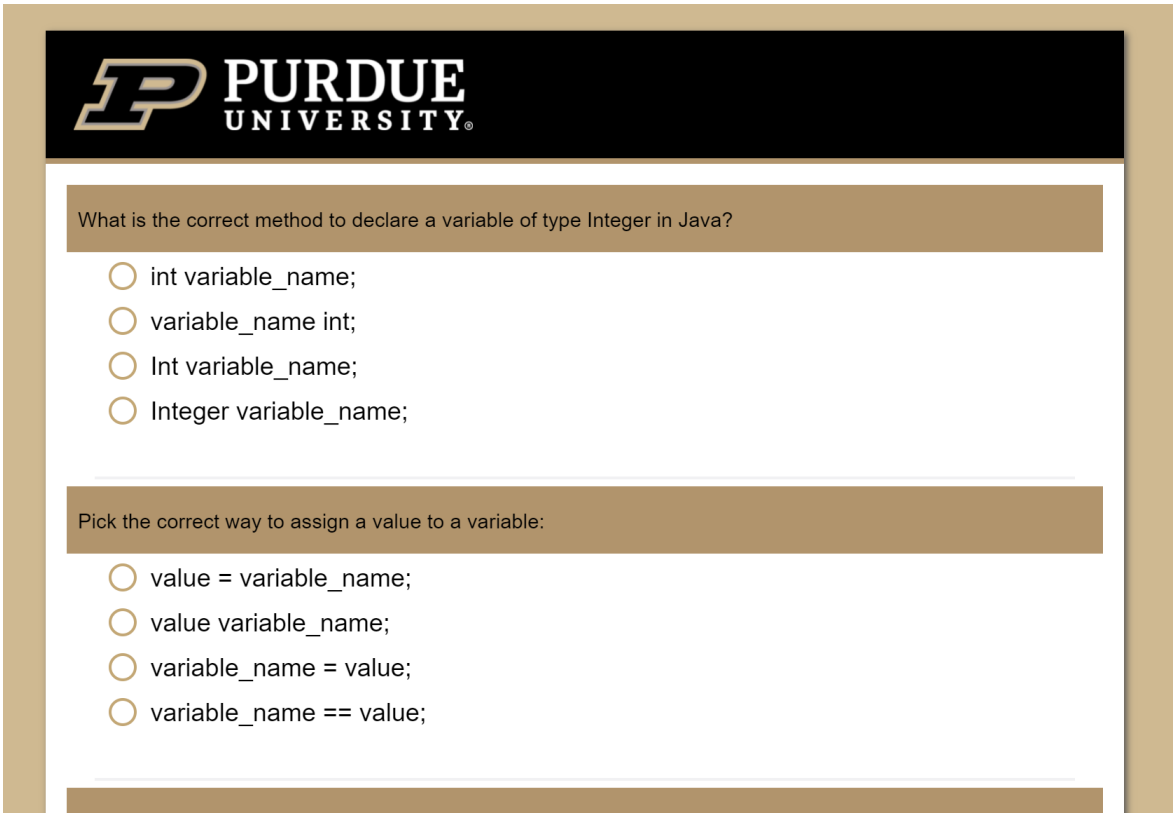


Figure 3.4. Problem answering interface on Qualtrics

validated by an experienced Java expert Shivashankar Guddadmath. Mr. Guddadmath is a founding director of a technology company and he suggested that the questions were valid for measuring students' Java programming knowledge. Please see Appendix A for the complete list of questions used in this study. Rather than simply giving participants the problems testing the knowledge related to the given week, BKT-LSTM understands what specific pieces of knowledge are the most lacking for students. In other words, BKT-LSTM will tell us what specific pieces of knowledge students must reinforce. After that, we will manually give those BKT-LSTM decided problems to participants in review quizzes. Therefore, we split the participants into two groups. The control group will have questions covering the given week, while the experimental group will have BKT-LSTM-decided problems. For the control group, in review quizzes, participants will have questions from two randomly picked pieces of knowledge until the given week. For example, in week 2, participants in the control group may have problems with Data and Control Flow. However, knowledge for the experimental

group is determined by BKT-LSTM. Participants will have questions from the first-lowest probability knowledge and the second-lowest probability knowledge. Therefore, though the review quizzes content in the control and experimental groups may vary, all the participants will have problems from two pieces of knowledge in each quiz. Figure 3.5 shows an example quiz setting for week two, including the knowledge String I/O and Control Flow.

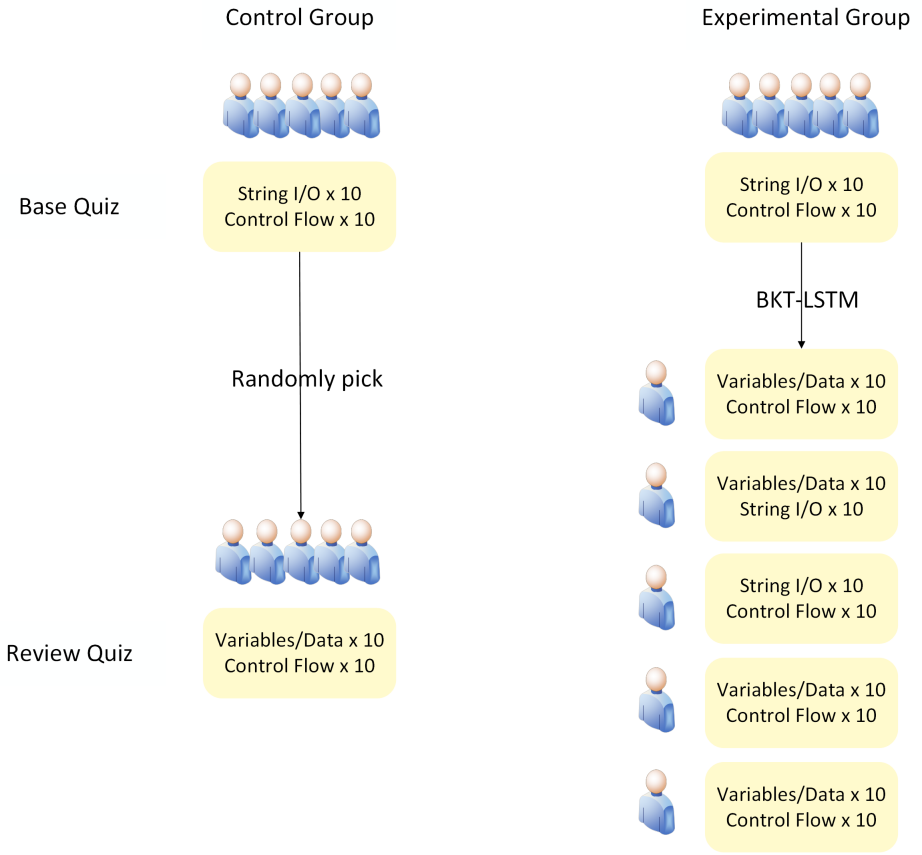


Figure 3.5. Example quizzes setting for week two: the control group will get two randomly picked knowledge until the given week; the experimental group will have BKT-LSTM-decided problems

In addition, to obtain more data, we determine to have twenty questions in each quiz. Twenty questions allow us to allocate four questions for each piece of knowledge in the pre-quiz and the post-quiz. The questions in pre-quiz and post-quiz come from five pieces of knowledge. Meanwhile, we can assign ten problems for each piece of knowledge in base quizzes and review quizzes. A piece of knowledge corresponds to several problems. Notice that our assumption is that one problem only relates to one piece of knowledge, not vice

versa. The number of questions per piece of knowledge will be the same in base quizzes and review quizzes to entirely update participants' learning profiles. For instance, if a participant has the lowest probability on String I/O in a base quiz, the participants will have another ten questions for String I/O in the review quiz. Participants' learning performance for each piece of knowledge will be completely updated after several weeks of review quizzes. Because no data is available in the first week, the content of review quiz one will be the same for the control and experimental group.

3.6.4 Missing data

In the experiment, missing data will be produced by skipping or missing questions or quizzes. K-Nearest Neighbors (KNN) imputation shows an impressive performance on tackling missing data [32], [33]. Unlike simple imputation methods, KNN imputation considers the relationship between the other features. For participants who miss some problems, the missing ones will be filled with the closest distance participants. The "closet distance" is measured by NaN-euclidean distance. The NaN-euclidean distance d_{NaN} is defined as follows:

$$d_{NaN} = \sqrt{w * d_{present}} \tag{3.11}$$

where

$$w = \frac{\#\ of\ coordinates}{\#\ of\ present\ coordinates} \tag{3.12}$$

and where $d_{present}$ stands for the euclidean distance of the non-missing coordinates (the present coordinates).

For instance, if a participant misses some questions in a quiz, blanks will be filled with data from the participants who have similar problem-answering patterns. Besides, to keep the feature correctness binary and avoid meaningless average values, we only consider one neighbor (K = 1) when using KNN imputation.

3.7 Data analysis

Participants will be randomly divided into the experimental group (the AI group) and the control group. Base quizzes and review quizzes will estimate participants' learning outcomes. Independent t-tests evaluate a significant difference between the two groups in base quizzes and review quizzes. Independent t-tests also estimate if there is a significant difference between base quizzes and review quizzes. Besides, Levene tests are required to demonstrate that the variance is equal between the two groups. Given that the number of participants is larger than 30, we assume that the data is normally distributed. KNN imputation handles missing data since the data is Missing At Random (MAR). We assume that students' learning states are stable. In other words, for the MAR data, missing data can be inferred from the existing ones [34], [35]. Moreover, KNN imputation outperforms other simple imputation methods [33]. In addition, we assume that the prior knowledge levels are roughly the same for participants in the two groups. Therefore, t-tests are needed on pre-quiz and base quizzes to ensure the prior knowledge levels are roughly the same. The effects of BKT-LSTM will be demonstrated by the t-test results between the base quizzes and review quizzes. The significance level will be set to .05.

4. RESULTS

This section presents the output of BKT-LSTM and data analysis results. Missing data is filled by KNN imputation. Some participants might take the quizzes carelessly as they finished the quizzes in a short time (< 3 minutes). However, some participants still achieved a high score in a short time. Therefore, time taken cannot be used as a reliable indicator. Indeed, it is difficult to define "careless answers" in questionnaires. Their answers were still kept in the dataset. Initially, there were 38 participants (Control = 19, Exp = 19). Three participants taking no quiz were removed from the dataset. In the data analysis part, there are 35 participants (Control = 17, Exp = 18). Table 4.1 describes the number of participants, mean, standard deviation, and standard error for each quiz. Regarding participants' demographic data, 65% were Sophomores, 26% were juniors, 6% were seniors, and 3% were graduate students. 97% participants were from the Polytechnic institute of Purdue University, while the remaining 3% came from other colleges of Purdue University. Besides, 50% of participants used Java as their primary programming language. 32% of participants reported using Python as their primary programming language, and 18% used C/C++. On the other hand, 50% of participants reported writing and debugging programs independently from a general programming ability. 47% of participants reported they were beginners and could only write simple programs. 3% of participants reported they were advanced Java users or had advanced users on other programming languages. In addition, participants did not know whether they were taking base quizzes or review quizzes. For example, pre-quiz was known to participants as quiz 1, and base quiz 1 was known as quiz 2, and so forth. We assume that participants in the two groups have the same prior knowledge levels. In the experiment, pre-quiz and base quizzes estimate participants' learning profiles towards specific pieces of knowledge. Therefore, t-tests are required to conduct on the pre-quiz and base quizzes to demonstrate that participants have the same prior knowledge levels. On the other hand, t-tests between base quizzes and review quizzes shows the effects of BKT-LSTM on participants. Also, t-test estimates if there is a significant difference between the two groups in the post-quiz.

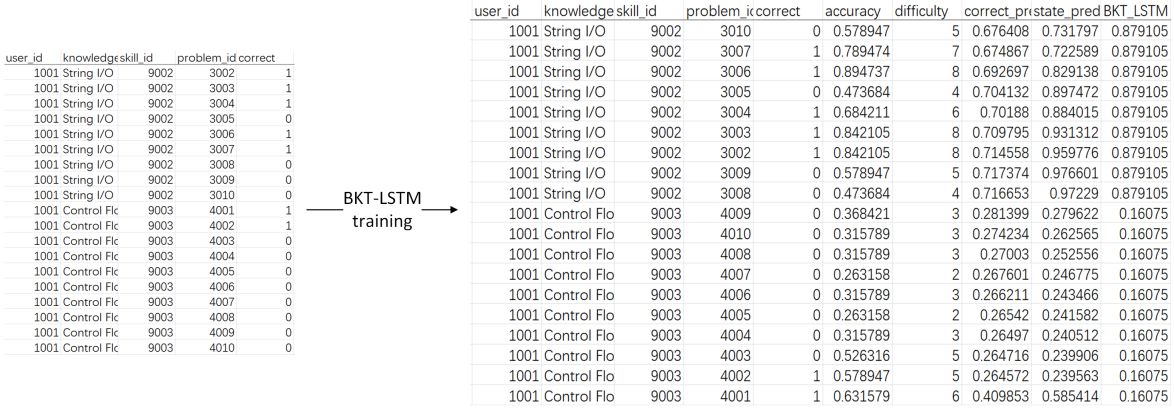
Table 4.1. Descriptive statistics for participants on quizzes

Group / Quiz	*N*	*Min*	*Max*	*Mean*	*SD*	*SE*
Control	17					
Pre-quiz		2.000	15.000	7.765	3.212	.779
Base 1		7.000	17.000	11.765	2.773	.673
Base 2		7.000	19.000	12.918	3.850	.934
Base 3		6.000	19.000	13.088	3.817	.926
Base 4		7.000	18.000	13.059	3.491	.847
Review 1		7.000	18.000	11.118	3.257	.790
Review 2		2.000	15.000	10.118	3.810	.924
Review 3		4.000	17.000	11.353	4.333	1.051
Review 4		2.000	17.000	8.971	4.403	1.068
Post-quiz		4.000	17.000	11.176	4.531	1.099
Experimental	18					
Pre-quiz		1.000	13.000	8.750	3.011	.710
Base 1		3.000	15.000	11.111	3.142	.740
Base 2		8.000	16.000	12.361	2.430	.573
Base 3		6.000	15.000	11.750	2.457	.579
Base 4		7.000	15.000	12.833	2.114	.498
Review 1		5.000	14.000	9.611	2.355	.555
Review 2		3.000	16.000	9.861	3.584	.845
Review 3		4.000	15.000	9.750	3.154	.743
Review 4		5.000	13.000	9.556	2.406	.567
Post-quiz		2.000	14.000	8.361	3.539	.834

N: Number, SD: Standard Deviation, SE: Standard Error

4.1 The outputs of BKT-LSTM

Participants took quizzes distributed by Qualtrics. The collected data were processed as .csv files. In the original dataset, it includes student_id, knowledge, knowledge_id, problem_id, and correctness. BKT-LSTM generated five extra columns: accuracy, difficulty, correct_pred, state_pred, and BKT_LSTM. The column accuracy is the correctness rate for each problem in the quizzes. The column state_pred is the acquirement probabilities for pieces of knowledge, which BKT generates. Finally, the acquirement probabilities for pieces of knowledge generated by BKT-LSTM are given in the column BKT_LSTM. Figure 4.1 shows the original data and the outputs of BKT-LSTM.



user_id	knowledge	skill_id	problem_id	correct
1001	String I/O	9002	3002	1
1001	String I/O	9002	3003	1
1001	String I/O	9002	3004	1
1001	String I/O	9002	3005	0
1001	String I/O	9002	3006	1
1001	String I/O	9002	3007	1
1001	String I/O	9002	3008	0
1001	String I/O	9002	3009	0
1001	String I/O	9002	3010	0
1001	Control Flc	9003	4001	1
1001	Control Flc	9003	4002	1
1001	Control Flc	9003	4003	0
1001	Control Flc	9003	4004	0
1001	Control Flc	9003	4005	0
1001	Control Flc	9003	4006	0
1001	Control Flc	9003	4007	0
1001	Control Flc	9003	4008	0
1001	Control Flc	9003	4009	0
1001	Control Flc	9003	4010	0

user_id	knowledge	skill_id	problem_id	correct	accuracy	difficulty	correct_pr	state_pred	BKT_LSTM
1001	String I/O	9002	3010	0	0.578947	5	0.676408	0.731797	0.879105
1001	String I/O	9002	3007	1	0.789474	7	0.674867	0.722589	0.879105
1001	String I/O	9002	3006	1	0.894737	8	0.692697	0.829138	0.879105
1001	String I/O	9002	3005	0	0.473684	4	0.704132	0.897472	0.879105
1001	String I/O	9002	3004	1	0.684211	6	0.70188	0.884015	0.879105
1001	String I/O	9002	3003	1	0.842105	8	0.709795	0.931312	0.879105
1001	String I/O	9002	3002	1	0.842105	8	0.714558	0.959776	0.879105
1001	String I/O	9002	3009	0	0.578947	5	0.717374	0.976601	0.879105
1001	String I/O	9002	3008	0	0.473684	4	0.716653	0.97229	0.879105
1001	Control Flo	9003	4009	0	0.368421	3	0.281399	0.279622	0.16075
1001	Control Flo	9003	4010	0	0.315789	3	0.274234	0.262565	0.16075
1001	Control Flo	9003	4008	0	0.315789	3	0.27003	0.252556	0.16075
1001	Control Flo	9003	4007	0	0.263158	2	0.267601	0.246775	0.16075
1001	Control Flo	9003	4006	0	0.315789	3	0.266211	0.243466	0.16075
1001	Control Flo	9003	4005	0	0.263158	2	0.26542	0.241582	0.16075
1001	Control Flo	9003	4004	0	0.315789	3	0.26497	0.240512	0.16075
1001	Control Flo	9003	4003	0	0.526316	5	0.264716	0.239906	0.16075
1001	Control Flo	9003	4002	1	0.578947	5	0.264572	0.239563	0.16075
1001	Control Flo	9003	4001	1	0.631579	6	0.409853	0.585414	0.16075

Figure 4.1. Original data sample and the outputs of BKT-LSTM

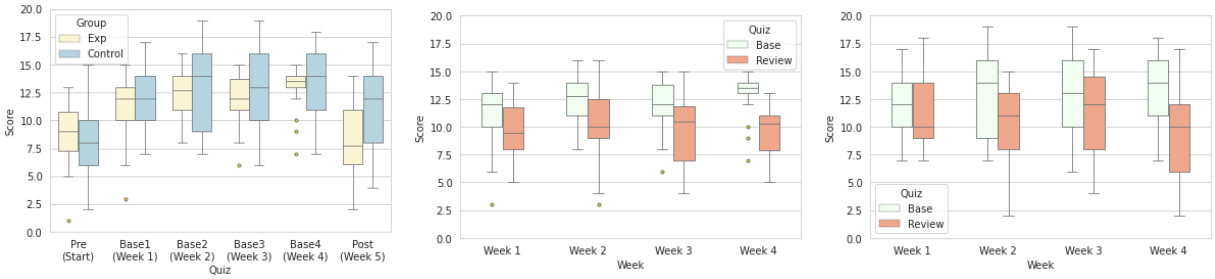
4.2 Prior knowledge levels

Pre-quiz and base quizzes estimate the prior knowledge levels of participants. Pre-quiz and base quizzes are the same for participants in the two groups. Box plots of pre-quiz and base quizzes between the two groups are shown in Figure 4.2. Box plots suggest that the prior knowledge levels of the control group are potentially higher than that of the experimental group. However, the results of t-tests indicated that there is no significant difference between the two groups in prior knowledge quizzes. The result of Levene's test on pre-quiz suggested that the variance between the two groups was equal, $F(2, 33) = .168$, $p = .684$. Similarly, the results of Levene's tests indicated that the variances between the two groups were equal in base quiz 1, $F(2, 33) = .003$, $p = .985$, base quiz 2, $F(2, 33) = 4.415$, $p = .043$, and base

quiz 4, $F(2, 33) = 3.952$, $p = .055$, respectively. However, the result of Levene's test on base quiz 3 suggested that the variance between the two groups was not equal, $F(2, 33) = 6.082$, $p = .019$. In addition, the result of t-test on pre-quiz indicated that there was no significant difference between the control group ($M = 7.765$, $SD = 3.212$) and the experimental group ($M = 8.750$, $SD = 3.011$), $t(33) = .937$, $p = .356$; $d = .317$. T-tests also showed that there was no significant difference between the two groups in base quizzes. Base quiz 1, control group ($M = 11.111$, $SD = 3.141$) and the experimental group ($M = 11.765$, $SD = 2.773$), $t(33) = -.651$, $p = .520$; $d = .221$. Base quiz 2, the control group ($M = 12.361$, $SD = 2.430$) and the experimental group ($M = 12.912$, $SD = 3.850$), $t(33) = -.509$, $p = .614$; $d = .171$. Base quiz 3, the control group ($M = 11.750$, $SD = 2.457$) and the experimental group ($M = 13.088$, $SD = 3.817$), $t(33) = -1.241$, $p = .224$; $d = .417$. Base quiz 4, the control group ($M = 12.833$, $SD = 2.114$) and the experimental group ($M = 13.059$, $SD = 3.491$), $t(33) = -.233$, $p = .817$; $d = .078$. The values of Cohen's d suggested that the difference between the two groups was also negligible. Based on the above results of t-tests and the values of Cohen's d, the prior knowledge levels of the two groups were assumed the same.

4.3 Base quizzes & review quizzes

The content of review quizzes varied from the experimental conditions. Participants in the control group had randomly picked questions from the knowledge until the given week. Participants in the control group had twenty questions for Variables/Data in week 1, the same for participants in the experimental group. In week 2, participants in the control group had ten Variables/Data questions and ten Control Flow questions. In week 3, participants in the control group had ten questions String I/O questions and ten Array questions. In the final review quiz, participants in the control group had ten Classes questions and ten Control Flow questions. However, participants in the experimental group had BKT-LSTM-determined questions. Review quizzes evaluated the effects of BKT-LSTM on participants' learning outcomes. Box plots of base and review quizzes for the two groups are shown in Figure 4.2.



(a) Prior knowledge quizzes (b) Experimental group (c) Control group

Figure 4.2. Box plots of prior knowledge quizzes, base and review quizzes for the control group and the experimental

On the other hand, t-tests between base quizzes and review quizzes evaluated the effects of BKT-LSTM on participants. For the experimental group, there was no significant difference between base quiz 1 ($M = 11.111$, $SD = 3.142$) and review quiz 1 ($M = 9.611$, $SD = 2.355$), $t(33) = 1.621$, $p = .114$; $d = .540$. The value of Cohen's d indicated a medium difference between base and review quiz 1. Also, there was no significant difference between base quiz 1 ($M = 11.765$, $SD = 2.773$) and review quiz 1 ($M = 11.118$, $SD = 3.257$) for the control group, $t(33) = .624$, $p = .537$; $d = .214$. The value of Cohen's d also suggested that the difference between the base and review quiz 1 for the control group was negligible. However, participants in the two groups both achieved significantly lower scores in review quiz 2 and review quiz 4 than that in base quiz 2 and base quiz 4, respectively. For the experimental group, participants had lower scores in review quiz 2 ($M = 9.861$, $SD = 3.584$) than that in base quiz 2 ($M = 12.361$, $SD = 2.430$), $t(33) = -2.449$, $p < .05$; $d = .816$. Cohen's d suggested that the difference between the two quizzes for the experimental group was large. Similarly, participants in the control group had lower scores in review quiz 2 ($M = 10.118$, $SD = 3.810$) than that in base quiz 2 ($M = 12.912$, $SD = 3.850$), $t(33) = -2.127$, $p < .05$; $d = .730$. The difference between base and review quiz 2 for the control group was relatively large. However, the Cohen's d for the control group was smaller than the experimental group in base and review quiz 2. Also, participants in the experimental group had lower scores in review quiz 4 ($M = 9.556$, $SD = 2.406$) than that in base quiz 4 ($M = 12.833$, $SD = 2.114$), $t(33) = -4.341$, $p < .001$; $d = 1.447$. Participants in the control group also scored lower in review quiz 4 ($M = 8.971$, $SD = 4.403$) than that in base quiz 4 ($M = 13.059$,

$SD = 3.491$), $t(33)$ = -3.000, $p < .05$; $d = 1.029$. The t-statistics and the values of Cohen's d for the experimental group were larger than the control group in base/review quiz 2 and base/review quiz 4. Meanwhile, participants in the experimental group had lower scores in the review quiz 3 ($M = 9.750$, $SD = 3.154$) than that in base quiz 3 ($M = 11.750$, $SD = 2.457$), $t(33)$ = -2.122, $p < .05$; $d = .707$. However, there was no significant difference between base quiz 3 ($M = 13.088$, $SD = 3.817$) and review quiz 3 ($M = 11.353$, $SD = 4.333$) for the control group, $t(33) = 1.240$, $p = .224$; $d = .425$.

4.4 Final learning outcomes

Pre-quiz and base quizzes estimate participants' prior knowledge levels. Post-quiz plays a role in evaluating the difference between the two groups after using BKT-LSTM. Figure 4.1 shows the data distribution of pre-quiz and post-quiz for the two groups. The result of Levene's test suggested the variance between the two groups was equal, $F(2, 33) = .397$, $p = .533$. Moreover, participants in the control group ($M = 11.176$, $SD = 4.531$) had higher scores than the participants in the experimental group ($M = 8.361$, $SD = 3.539$), $t(33)$ = -2.055, $p < .05$; $d = .693$. The value of Cohen's d suggested that the difference between the two groups was relatively large. The results suggested that there were no significant difference between the two groups in prior knowledge quizzes. In other words, the prior knowledge of the two groups were at the same levels. However, the results on both the control group and the experimental group showed that participants had lower scores on review quizzes than that in base quizzes. Finally, post-quiz suggested that the learning outcomes of the control group were better than the experimental group. Results will be discussed in the next section.

5. DISCUSSION

The results suggested that the participants' prior knowledge in the two groups was at the same level. Also, participants in both the experimental and control groups had lower scores in review quizzes than in quizzes. Moreover, the post-quiz indicated that participants in the control group had higher scores than the experimental group. This section will discuss the results and explain the potential effects of BKT-LSTM on participants' learning outcomes.

5.1 Results interpretation

Pre-quiz and base quizzes measured participants' prior knowledge levels. The results of t-tests suggested that there was no significant difference between the two groups in pre-quiz and base quizzes. Therefore, the prior knowledge of the two groups were at the same level can be assumed. BKT-LSTM affected participants that were at the same prior knowledge level. However, except for base quiz 1 and review quiz 1, the results suggested that participants in both the control and experimental group had lower scores in review quizzes than in base quizzes. Given that no data was available in week 1, review quiz 1 was the same for participants in the two groups. Hence, it was expected that review quiz 1 did not affect participants' learning outcomes. However, in pre-quiz, participants in the experimental group had slightly higher scores than those in the control group. Suggested by t-statistic (0.937) and Cohen's d (0.317), there might still be some difference that affected the results in pre-quiz though the result was not significant. Therefore, we should consider using pre-quiz as a covariate in future studies.

For the experimental group, results indicated that participants had significantly lower scores in review quiz 2, review quiz 3, and review quiz 4 than that in base quiz 2, base quiz 3, and base quiz 4, respectively. BKT-LSTM determined the review quizzes for participants in the experimental group. The questions came from the pieces of knowledge that BKT-LSTM thought they were most lacking. Therefore, the results proved that BKT-LSTM did successfully predict the most lacking knowledge for participants. Indeed, except for base quiz 3, participants in the control group also had lower scores in review quizzes than in base quizzes. The questions for participants in the control group were randomly picked from

the knowledge until the given week. Review quizzes for participants in the control did help their learning to some extent, though the questions were not personalized. However, the experimental and control group was significantly different in base and review quiz 3. For base/review quiz 2 and 4, participants in the experimental group had lower t-statistics than those in the control group. The results suggested that the score difference between base quizzes and review quizzes for the experimental group was more often significantly different (three quizzes) compared to the control group (two quizzes). Besides, the values of Cohen's d suggested that the effect sizes between base and review quizzes for the experimental group were larger than the control group. In other words, participants in the experimental group had worse performance in review quizzes than in the control group. Given that participants' prior knowledge levels were the same, the difference was most likely brought by BKT-LSTM. BKT-LSTM gave questions from the knowledge they were most lacking and thereby lowering the scores in review quizzes.

Finally, post-quiz estimated participants' final learning outcomes. In post-quiz, participants in the experimental group had significantly lower scores than in the control group. Initially, it was expected that participants in the experimental group would have better learning outcomes than in the control group. Participants in the experimental group had personalized learning content generated by BKT-LSTM; therefore, they would have better learning outcomes. The following reasons may cause the final learning outcomes. First, participants in the experimental group kept answering questions from the knowledge they were most lacking. Complex questions may lower participants' learning initiatives. In post-quiz, the attendance of participants in the experimental group was lower than in the control group. On the contrary, participants in the control group had questions from relatively easy knowledge. Easy questions may make them feel confident, and therefore improve their learning initiatives. The above findings were consistent with the feedback intervention study: the relationship that simple tasks enhance learning performance; however, complex tasks lower learning performance [22]. Second, participants did not have solutions from the quizzes. Participants may lack a sense of achievement in taking quizzes, especially since the questions are complex. It further frustrated the participants in the experimental group and lowered their learning initiatives. BKT-LSTM worked on only three review quizzes, so participants'

learning profiles were not sufficiently established. Also, the entire experiment only lasted for five weeks. Short experiment duration may result in not significant results between the two groups. In addition, the experiment only considered five pieces of knowledge. Moreover, quizzes did not include the five pieces of knowledge until the final week. Therefore, review quizzes for the two groups may overlap to some extent. For example, in review quiz 2, participants in the control group had ten Variables/Data questions and ten Control Flow questions. Meanwhile, most participants in the experimental group also had similar question combinations. Review quizzes for participants in the control group seemingly also helped them with the learning. In addition, except for the pre-quiz and base quiz 1, the dataset showed that the number of missing data in the experimental group was more than that in the control group (the difference was more than two participants). For example, eight participants in the experimental group skipped the post-quiz, while only three participants in the control group skipped the post-quiz. The missing data difference between the two groups, to some extent, reflected that the willingness and the engagement on quizzes taking of participants in the experimental group were lower than those in the control group. Therefore, it would also be essential to explore the connection between students' engagement and learning performance in future studies [12]. Shute suggested that students with different achievement levels in different timing of feedback should have different types of feedback [22]. For example, in this study, the timing of the feedback was "immediate". In the timing of immediate feedback, students with low achievement and low prior knowledge levels should be given "correct response" and "response contingent." Essentially, Shute argued that students having low performance and those having high performance were suitable for different types of feedback. Based on the research finding, we may consider separating participants in each group with low performance and high performance and evaluating significant differences in future studies.

5.2 Other applications

In this study, quizzes were manually given to participants. Manually giving quizzes to participants limits the number of participants and pieces of knowledge. It would be unreal-

istic to manually give participants quizzes if too many participants and pieces of knowledge are considered. Integrating BKT-LSTM into an online learning platform or exercise system would be a solution. This makes our work may also apply to applications outside of the traditional classroom. To help students' learning, different types of educational technology are drawing more and more attention. For example, one could consider applying and testing BKT-LSTM in the context of computational learning [36], [37] and tutorials [38]. Also, educational games [39]–[41] and Virtual Reality learning environment [42]–[44] would help students better understand abstract concepts than in traditional classrooms. BKT-LSTM's predictive capability might make the virtual learning environment more personalized and realistic. In addition, BKT-LSTM might help capture students' learning behaviors [45]–[48], and thereby optimize the class setting. From the perspective of model performance, BKT-LSTM can consider more student features to overcome the learning transfer drawback. However, dimension reduction might be required with much more features [49].

5.3 Limitation

The results showed that participants in both groups had lower scores in review quizzes than in base quizzes. The score difference between base quizzes and review quizzes for the experimental group was more often significantly different (three quizzes) compared to the control group (two quizzes). The experiment demonstrated that BKT-LSTM did successfully predict participants' most lacking knowledge to some extent. However, several limitations for the study should be noticed. Participants would have 3% extra credits by completing all the quizzes. To avoid participants skipping quizzes, they would receive 0.1% extra credit by taking a quiz and 2% extra credits by taking all the quizzes. However, 3% extra credits may not be enough to encourage students to take all the quizzes seriously. In other words, the experiment rewards were not enough. Besides, participants did not have solutions after taking quizzes. Therefore, they did not have opportunities to correct themselves. It may frustrate participants, especially when they are facing complex questions. Moreover, BKT-LSTM assumes students will not forget the learned knowledge. However, in reality, students may forget the learned knowledge to some extent as the course continues. Therefore, participants

who had lower scores in review quizzes than in base quizzes might be due to the material being fresher in base quizzes. In other words, they had lower scores in review quizzes than in base quizzes was because they forgot the learned knowledge to some extent. Finally, the experiment only lasted for five weeks. BKT-LSTM may not sufficiently learn participants' learning profiles under such a short experiment duration. Also, the experiment only considered five pieces of knowledge, resulting in the overlapping of the question combination for the experimental group and the control group.

6. CONCLUSION

This study explored the effects of BKT-LSTM on students' learning performance. Participants were randomly separated into the control group and the experimental group. Pre-quiz and base quizzes estimated participants' prior knowledge levels. Participants in the control group had questions from two randomly picked knowledge until the given week. However, participants in the experimental group had BKT-LSTM decided questions. BKT-LSTM identified participants' most lacking knowledge. Participants in the experimental group had questions from the knowledge with the lowest acquirement probability and the second-lowest acquirement probability. BKT-LSTM determined the content of review quizzes for the experimental group.

The results showed that participants' prior knowledge levels were the same. Also, participants in both groups had lower scores in review quizzes than in base quizzes. However, the score difference between base quizzes and review quizzes for the experimental group was more often significantly different (three quizzes) compared to the control group (two quizzes). The difference demonstrated that BKT-LSTM effectively predicted the knowledge that participants most lacked to some extent. In post quiz, participants in the control group had significantly higher scores than those in the experimental group. The result implied that BKT-LSTM affected participants' learning outcomes negatively. For participants in the experimental group, continuous complex questions may frustrate their learning initiatives. On the contrary, relatively easy questions potentially improved the learning initiatives for participants in the control group.

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A. APPENDIX FOR QUESTION BANK

Appendix A includes the questions bank for the five selected pieces of knowledge (Variables/Data, String I/O, Control flow, Array, and Classes). The question bank includes 140 self-developed questions and 106 adapted questions from publicly available question banks [1] [2]. All the questions were validated by an experienced Java expert. Correct answers were marked red.

A.1 Variables/Data

(2001) Self-developed

1) What is the correct method to declare a variable of type Integer in Java?
   a) int variable_name;
   b) variable_name int;
   c) Int variable_name;
   d) Integer variable_name;

(2002) Self-developed

2) Pick the correct way to assign a value to a variable:
   a) value = variable_name;
   b) value variable_name;
   c) variable_name = value;
   d) variable_name == value;

(2003) Self-developed

3) In Java it is possible to declare and initialize a variable with a one-line code, pick the option with the incorrect syntax:
   a) int number = 1;
   b) boolean flag = true;
   c) String name = "CNIT25501";
   d) int number == 1;

(2004) Self-developed

4) Which of the following is NOT a primitive data type in Java?
   a) short
   b) byte
   c) long
   d) String

[1] "JAVA programming final exam questions", [Online]. Available: https://wenku.baidu.com/view/5010c983c67da26925c52cc58bd63186bdeb9245.html [Accessed:30-Jun-2021].

[2] "JAVA programming final exam questions and answers", [Online]. Available: https://wenku.baidu.com/view/8c6903d48f9951e79b89680203d8ce2f006665ed.html?rec_flag=default&fr=pc_newview_relate1001_12wk_rec_doc1001_138c6903d48f9951e79b89680203d8ce2f006665ed&sxtsI624534888041 [Accessed:30-Jun-2021].

(2005) Self-developed

5) What is the default value of an instance variable of type boolean?
   a) true
   b) false
   c) null
   d) 0

(2006) Self-developed

6) It is possible to convert an integer value into a boolean value.
   a) True
   b) False

(2007) Self-developed

7) A reference variable contains a reference to an object.
   a) True
   b) False

(2008) Self-developed

8) Which of the following type conversions are NOT automatic in Java?
   a) int => double
   b) char => int
   c) double => short
   d) float => double

(2009) Self-developed

9) In Java n+=4; is the same as n = n + 4;
   a) True
   b) False

(2010) Self-developed

10) Pick the right method to use the increment operator:
   a) variable_name++;
   b) ++variable_name;
   c) variable_name+;
   d) +variable_name;

(2011) Self-developed

11) What is the output of the following code?

```
public static void main(String[] args)
{
   double a = 10.5 % 2;
   double b = 10.5 / 2;
   double c = 10.5 * 2;
   System.out.print(a);
   System.out.print(b);
   System.out.print(c);
}
```

   a) 0.5 5.25 21.0
   b) 10 5.25 21
   c) 10.5 5 21.0
   d) 0.5 5.25 21

(2012) Self-developed
12) In this code, args is considered to be a/an,

```
public static void main(String[] args){
    //some code;
}
```

a) Class
b) Constant
c) Integer
d) Array

(2013) Self-developed
13) Given the following code snippet:

```
public static void main(String[] args){
    int a = 5;
    int b = 7;
    int c = a*b;
    double c = a*b;
    System.out.println(c);
}
```

What will be printed?
a) 35
b) 35.0
c) "5*7"
d) No Output

(2014) Adapted from Q4, page 5 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: 以下哪个不是Java的原始数据类型?
(Which of the following is NOT a primitive data type in Java?)

a) int
b) Boolean
c) float
d) char

14) Which of the following is NOT a primitive data type in Java?
a) int
b) double
c) byte
d) long int

(2015) Adapted from Q2, page 16 in "JAVA programming final exam questions", 2017, Baidu Library [1]
Original: 下列 ___ 是Java合法的标识符
(The following ___ is a valid identifier in Java)
a) static
b) 5stu
c) -3e
d) _atm

15) Which of the following is NOT a valid identifier in Java?
a) $var
b) _pop
c) new
d) stu1

(2016) Self-developed
16) Which of the following is the correct way for adding Java annotation?
a) /* I love CNIT 25501 */
b) // I love CNIT 25501 */
c) /** I love CNIT 25501 */
d) /* I love CNIT 25501 **/

(2017) Adapted from Q2, page 16 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with problem 2015

17) Which of the following is NOT a valid identifier in Java?

a) STRING
b) INT
c) de_$f123
d) void

(2018) Self-developed

18) Given the following Java code snippet:

```
public static void main(String[] args){
    int a = 8;
    int b = 3;
    int c = a / b;
    double c = a / b;
    System.out.println(c);
}
```

What will be printed?

a) 2.666666…
b) 2
c) 2.6
d) 2.0

(2019) Self-developed

19) Which of the following is correct for initializing a boolean variable?

a) boolean a = 1;
b) boolean a = (“a” > “z”);
c) boolean a = “False”;
d) boolean a == 1;

(2020) Adapted from Q4, page 23 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 下列程序运行后，输出的结果是 ___

(Given the following Java code snippet, the output is ___)

```
public static void main(String args[]) {
        int c = 5;
        System.out.print(c);
        System.out.print(c++);
        System.out.print(c);
}
```

20) What is the output of the following Java code snippet?

```
public static void main(String args[]) {
    int a = 10;
    System.out.print(a--);
    System.out.print(a++);
    System.out.print(a);
}
```

a) 91010
b) 101010
c) 91111
d) 91110

(2021) Self-developed

21) Which of the following is the correct operator priority?

a) “()” > “!” > “=” > “+” > “&&”
b) “()” > “!” > “+” > “&&” > “=”
c) “()” > “+” > “=” > “!” > “&&”
d) “()” > “+” > “&&” > “!” > “=”

(2022) Self-developed

22) Which of the following is the correct method to declare a variable?

a) float f = 1.1
b) double d = 34.4
c) int i = 4L
d) char a = int(1.12)

(2023) Self-developed

23) We can change the value of a **final** variable

a) True
b) False

(2024) Adapted from Q1, page 16 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: 下列关于java语言的叙述中，正确的是 ___
(Which of the following is TRUE about Java ___)

a) 机器语言 (machine language)
b) 汇编语言 (assembly language)
c) 面向过程的语言 (process-oriented programming language)
d) 面向对象的语言 (object-oriented programming language)

24) Which of the following is TRUE about Java?

a) Java is a machine language
b) Java is an assembly language
c) Java is an object-oriented programming language
d) Java is a process-oriented programming language

(2025) Adapted from Q7, page 16 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: 执行下列程序段后，b，x，y的值正确的是 ____
(Given the following Java code snippet, the values of b, x, y is ___)

```
int x = 6;
int y = 8;
boolean b = x < y || ++x == --y;
```

a) true, 6, 8
b) false, 7, 7
c) true, 7, 7
d) false, 6, 8

25) Given the following Java code snippet:

```
int x = 12;
int y = 11;
boolean b = (x < y || --x == y);
```

What is the value of the variables b, x, and y, respectively?

a) true, 12, 11
b) true, 11, 11
c) false, 11, 11
d) false, 12,10

(2026) Adapted from Q7, page 16 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: the same with 2025

26) Given the following Java code snippet:

```
int x = 6;
int y = 8;
boolean b = (x < y || x++ == y);
```

What is the value of the variables b, x, and y, respectively?

a) true, 6, 8
b) true, 7, 8
c) false, 6, 8
d) false, 7, 8

(2027) Adapted from Q7, page 16 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with 2025

27) Given the following Java code snippet:

```
int x = 6;
int y = 8;
boolean b = (x < y && x++ == y);
```

What is the value of the variables b, x, and y, respectively?
a) true, 6, 8
b) true, 7, 8
c) false, 6, 8
d) false 7, 8

(2028) Adapted from Q7, page 16 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with 2025

28) Given the following Java code snippet:

```
int x = 6;
int y = 8;
boolean b = (x < y && ++x == --y);
```

What is the value of the variables b, x, and y, respectively?
a) true, 6, 8
b) true, 7, 7
c) false, 6, 8
d) false, 7, 7

(2029) Adapted from Q7, page 16 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with 2025

29) Given the following Java code snippet:

```
int x = 6;
int y = 8;
boolean b = (x < y || ++x == --y);
```

What is the value of the variables b, x, and y, respectively?
a) true, 6, 8
b) true, 7, 7

(2030) Adapted from Q11, page 16 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: 以下关于Java程序叙述正确的是 ___
(Which of the following statements is TRUE)

a) Java程序中main函数必须位于最前
(In a Java program, the main method must be at the front of all the methods)
b) Java程序每行只能有一条语句
(In a Java program, there can only be one statement per line)
c) 在对一个Java程序的编译过程中，可以发现注释的错误
(In a Java program, we can detect the errors in the annotation when compiling)
d) Java程序必须有一个主函数
(In a Java, program, there must be the main method)

30) Which of the following statements is TRUE?
a) In a Java program, there can only be one statement per line
b) In a Java, program, there must be the main method
c) In a Java program, the main method must be at the front of all the methods
d) In a Java program, we can detect the errors in the annotation when compiling

(2031) Self-developed
31) Given the following Java code snippet:

```
int a = 1;
int b = 1;
boolean m = (a++ > b);
```

What is the value of a and m, respectively?
a) 1, true
b) 2, true
c) 1, false
d) 2, false

(2032) Self-developed
32) Given the following Java code snippet:

```
int a = 1;
int b = 1;
boolean m = (++a > b);
```

What is the value of a and m, respectively?
a) 1, true
b) 2, true
c) 1, false
d) 2, false

(2033) Self-developed
33) What is the data type of the expression 8 / 9.2 * 5?
a) short
b) int
c) double
d) float

(2034) Self-developed
34) Given the following Java code snippet:

```
int a = 8;
int b = 4;
double c = a / b;
```

What is the value of the variable c?
a) 2
b) 2.0
c) 4.0
d) 8

(2035) Self-developed
35) Which of the following is NOT the correct variable declaration?
a) double d = 545;
b) char c = “a”;
c) int i = 321;
d) float f = 4.0;

(2036) Translated from Q56, page 21 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: 设 x = 1, y = 2, z = 3, 则表达式 y += z-- / ++x的值是（）
(Assume x =1, y = 2, z = 3, the value of the expression y += z-- / ++ x is ())

a) 3
b) 3.5
c) 4
d) 4.5

36) Given the following Java code snippet:

```
int x = 1;
int y = 2;
int z = 3;
```

```
y += z-- / ++ x;
```

What is the value of variable y?

a) 3
b) 3.5
c) 4
d) 4.5

(2037) Adapted from Q56, page 21 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with 2036

37) Given the following Java code snippet:

```
int x = 1;
int y = 1;
int z = 1;
y += z-- / ++ x;
```

What are the values of variables z and x, respectively?

a) 1, 1
b) 0, 2
c) 2, 0
d) 2, 1

(2038) Adapted from Q1, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: 已知： int a = 8, b = 6; 则，表达式++a-b++的值是（）
(Given that int a = 8, b = 6, the value of the expression ++a-b++ is ())

38) Given the following Java code snippet:

```
int a = 8;
int b = 6;
int c = ++a - b++;
```

What is the value of c?

a) 2
b) 1
c) 3
d) 4

(2039) Adapted from Q1, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with 2038

39) Given the following Java code snippet:

```
int a = 3;
int b = 4;
int c = ++a - ++b;
```

What is the value of c?

a) -2
b) -1
c) 3
d) 4

(2040) Adapted from Q1, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with 2038

40) Given the following Java code snippet:

```
int a = 7;
int b = 6;
float c = a / b;
```

What is the value of c?

a) 1.1666666...
b) 1.0
c) 1
d) 0

(2041) Adapted from Q1, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with 2038

41) Given the following Java code snippet:

```
int a = 2;
int b = 3;
double c = a + b;
```

What is the value of c?

a) 5
b) 5.0
c) 5.00
d) 2 + 3

(2042) Self-developed

42) Which of the following is the “and” operator in Java?

a) ||
b) and
c) &&
d) *

(2043) Self-developed

43) Which of the following is the “or” operator in Java?

a) ||
b) or
c) &&
d) !=

(2044) Adapted from Q22, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: int x = 2, y = 5; boolean b; b = ++x > 4 && ++y < 3;, 则x，y，b的值为（）

(int x = 2, y = 5; boolean b; b = ++x > 4 && ++y < 3;, the values of x, y, b are ())

44) Given the following Java code snippet:

```
int x = 2;
int y = 5;
boolean b = ++x > 4 && ++y < 3;
```

What are the values of x and y, respectively?

a) 2, 5
b) 3, 5
c) 2, 6
d) 3, 6

(2045) Adapted from Q22, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with 2044

45) Given the following Java code snippet:

```
int x = 2;
int y = 5;
boolean b = ++x > 4 && ++y < 3;
```

What is the value of b?

a) 0
b) 1
c) true
d) false

(2046) Adapted from Q23, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: float f = 33.7; f = f % 10;, 则 f 的值为 ___

(float f = 33.7; f = f % 10;, the value of f is ___)

46) Given the following Java code snippet:

```
float a = 33;
a = a % 10;
```

What is the value of a?

a) 3
b) 33
c) 10
d) Error

(2047) Adapted from Q4, page 23 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with problem 2020

47) Given the following Java code snippet:

```
int c = 1;
System.out.print(c);
System.out.print(c++);
System.out.print(c);
```

What is the output?

a) 111
b) 121
c) 122
d) 112

(2048) Adapted from Q4, page 23 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: the same with problem 2020

48) Given the following Java code snippet:

```
int c = 1;
System.out.print(c);
System.out.print(++c);
System.out.print(c++);
```

What is the output?

a) 111
b) 122
c) 123
d) 112

(2049) Adapted from Q3, page 1 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]

Original: 设x = 2，则表达式(x++) / 3的值是 ____

(Assume x = 2, the value of the expression (x++) / 3 is ____)

49) Given the following Java code snippet:

```
int x = 2;
System.out.println(x++ / 3);
```

What is the output?

a) 0
b) 1
c) 2
d) 3

(2050) Adapted from Q3, page 1 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]

Original: the same with 2049

50) Given the following Java code snippet:

```
int x = 2;
System.out.println(++x / 3);
```

What is the output?

a) 0
b) 1
c) 2
d) 3

(2051) Self-developed

51) Which of the following is the correct parameter for the main method?

a) String args
b) String[ ] args
c) Char args
d) StringBuffer args[ ]

(2052) Adapted from Q11, page 6 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]

Original: 以下代码段执行的输出结果为（）

(the output of the following code is ())

```
int x = -3;
int y = -10;
System.out.println(x % y);
```

a) -1
b) 2
c) 1
d) 3

52) Given the following Java code snippet:

```
int x = -3;
int y = -10;
System.out.println(x % y);
```

What is the output?

a) 2
b) 1
c) -3
d) 3

(2053) Adapted from Q38, page 20 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 若定义有变量float f1, f2 = 8.0; 下列说法正确的是（）
(Assume we have float f1, f2 = 8.0; which of the following is TRUE())

a) 变量f1，f2均被初始化为8.0
(The variables x and y are both declared and initialized to 8.0)
b) 变量f1没有被初始化，f2被初始化为8.0
(Only variable f2 is initialized to 8.0, while f1 is not)
c) 变量f1，f2均未被初始化
(None of the variables are initialized)
d) 变量f2没有被初始化，f1被初始化为8.0
(Only variable f1 is initialized to 8.0, while f2 is not)

53) Which of the following is TRUE about the statement “double x, y = 1.0;”?

a) The variables x and y are declared and initialized to 1.0 at the same time
b) Only variable x is initialized
c) Only variable y is initialized
d) None of the variables are initialized

(2054) Adapted from Q38, page 20 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with 2053

54) What is the correct method to declare and initialize x and y at the same time?

a) boolean x, y = true;
b) int x = 10, y = 5;
c) double x, y = 1.0, 1.0;
d) String x = “abc”, String y = “def”;

(2055) Self-developed

55) Which of the following is the keyword in Java

a) name
b) true
c) bad
d) world

(2056) Self-developed

56) Which of the following is TRUE about float and double in Java?

a) They are the same thing
b) float has more precision than double
c) double has more precision than float
d) float is a 64-bit single-precision floating-point number

(2057) Adapted from Q9, page 12 in “《JAVA Programming》Final Exam Questions and Answers”, 2019, Baidu Library [2]

Original: 假设 x = 13, y = 4, 则表达式 x % y != 0 的值是（），数据类型是（）
(Assume x = 13, y = 4, the value of the expression x % y != 0 is (), data type is ())

57) Given the following Java code snippet:

```
int x = 13;
int y = 4;
System.out.println(x % y != 0);
```

What is the output?

a) 0
b) 1
c) false
d) true

(2058) Adapted from Q9, page 12 [2], Original: the same with 2057

58) Given the following Java code snippet:

```
int x = 8;
int y = 4;
System.out.println(x % y == 1);
```

What is the output?

a) 0
b) 1
c) false
d) true

A.2 String I/O

(3001) Self-developed

1) Strings are objects.
   a) True
   b) False

(3002) Self-developed

2) Which is the correct way to declare a variable of type String in Java?
   a) variable_name = String;
   b) String variable_name;
   c) String == variable_name;
   d) string variable_name;

(3003) Self-developed

3) Pick the correct method to assign a value to a variable of type String:
   a) a = 45;
   b) a == “45”;
   c) a = “45”;
   d) a 45;

(3004) Self-developed

4) You can call methods on strings.
   a) True
   b) False

(3005) Self-developed

5) What is the return type for the String function length()?
   a) int
   b) char
   c) double
   d) boolean

(3006) Self-developed

6) Index starts from what value for the variable of type String?
   a) 1
   b) 0
   c) Depends on the length of the variable
   d) 2

(3007) Self-developed

7) Which is the correct method to concatenate strings?
   a) String 1 ++ String 2;
   b) String 1 + String 2;
   c) String 1 = String 2;
   d) String 1 String 2;

(3008) Self-developed

8) The length() of the String “Hello World” is:
   a) 10
   b) 12
   c) 9
   d) 11

(3009) Self-developed

9) Strings are immutable.
   a) True
   b) False

(3010) Self-developed

10) The String is a primitive data type.
   a) True
   b) False

(3011) Self-developed

11) The substring( ) method creates a new char array that represents the new string.
   a) True
   b) False

(3012) Self-developed

12) Which is the recommended method to compare two strings?
   a) a == b;
   b) a.equals(b);

(3013) Adapted from Q1, page 5 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 阅读下面的程序代码，回答问题
(Answer questions from the following code snippet)

```
String s1 = new String(“abcde”);
String s2 = new String(“abcde”);
boolean b1 = s1.equals(s2);
boolean b2 = s1 == s2;
System.out.print(s1 + “ ” + s2);
```

13) What is the output of the following main program?

```
public static void main(String[] args){
    String str1 = "CNIT";
    String str2 = "25501";
    String value = str1+ “  “ +  str2;
    System.out.println(value);
}
```

   a) “CNIT” + “25501”
   b) CNIT 25501
   c) CNIT25501
   d) No output

(3014) Self-developed
14) What is the output of the following main program?

```
public static void main(String[] args){
   String test = "CNIT";
   int  number = 25501;
   String value = test + number;
   System.out.println(value);
}
```

a) CNIT + 25501
b) CNIT 25501
c) CNIT25501
d) No output

(3015) Self-developed
15) What is the output of the following main program?

```
public static void main(String[ ] args) {
   String test = "abcdef";
   System.out.println(test.substring(5));

}
```

a) ef
b) a
c) f
d) fa

(3016) Self-developed
16) Which of the following is NOT a method of the String class?
a) equals()
b) concat()
c) append()
d) indexOf()

(3017) Self-developed
17) What type of error will occur in the following code?

```
String s = null;
s.concat('abc');
```

a) ArithmeticException
b) NullPointerException
c) IOException
d) ClassNotFoundException

(3018) Self-developed
18) Which value of the following statement is NOT equal to TRUE?
a) "CNIT 25501" == "CNIT 25501"
b) "CNIT 25501".equals("CNIT 25501")
c) "CNIT 25501" = "CNIT 25501"
d) "CNIT 25501".equals(new String("CNIT 25501"))

(3019) Self-developed
19) Which of the statements returns true?
a) "CNIT 25501" == "CNIT 25501"
b) "CNIT".equals("25501")
c) "CNIT 25501".equals(new String("25501"))
d) ("CNIT 25501".substring(1, 4)).equals("CNIT")

(3020) Self-developed
20) Which of the following is TRUE for the variable s?

```
String[ ] s = new String[10];
```

a) s.length() is 10
b) s[10] is null
c) s[9] is null
d) s[9] is 0

(3021) Adapted from Q3, page 1 in "JAVA programming final exam questions", 2017, Baidu Library [1]
Original: 应用程序的main方法有以下语句，则输出结果是（）
(Assume we have the following code in the main method. The output is ())

```
String s = "xxxxxxxxxxxxxxx#123#456zzzzz";
int n = s.indexOf("#");
int k = s.indexOf("#", n + 1);
String s2 = s.substring(n + 1, k);
System.out.println(s2);
```

a) 123456
b) 123
c) xxxxxxxxxxxxxxx
d) zzzzz

21) Assume that we have the following code snippet in the main method:

```
String s = "xxx#123#456";
int n = s.indexOf("#");
String s2 = s.substring(n + 1, 7);
System.out.println(s2);
```

What is the output?
a) 123
b) xxxx
c) 123#
d) #123

(3022) Adapted from Q3, page 1 in "JAVA programming final exam questions", 2017, Baidu Library [1]
Original: the same with problem 3021

22) Assume that we have the following code snippet in the main method:

```
String s = "xxx#123#456";
String s2 = s.substring(8, 11);
System.out.println(s2);
```

What is the output?
a) 456
b) 123
c) #45
d) 3#4

(3023) Adapted from Q1, page 5 in "JAVA programming final exam questions", 2017, Baidu Library [1]
Original: the same with problem 3013

23) What is the value of the following boolean variable b?

```
String s1 = new String("abc");
String s2 = new String("abc");
boolean b = (s1 == s2);
```

a) True
b) False

24) What is the value of the following boolean variable b?

```
String s1 = new String("abc");
String s2 = new String("abc");
boolean b = (s1.equals(s2));
```

a) true
b) false

(3025) Adapted from Q1, page 5 in "JAVA programming final exam questions", 2017, Baidu Library [1]
Original: the same with problem 3013

25) What is the value of the following boolean variable b?

```
String s1 = new String("abc");
String s2 = new String("abc");
boolean b = (s1.equals(new String("abc")));
```

a) true
b) false

(3026) Adapted from Q3, page 11 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: 已知如下定义：String s = "story"; 下面哪个语句不是合法的（）
(Assume we have String s = "story"; which of the following is NOT valid ())

a) s += "books";
b) s = s + 100;
c) int len = s.length;
d) String t = s + "abc";

26) Assume we have String s = "CNIT"; which of the following is NOT valid (error)?
a) s += "25501";
b) s += 10;
c) int len = s.length;
d) String temp = s + "a";

(3027) Self-developed
27) Which of the following is FALSE about strings in Java?
a) s.length() returns the length of the string s
b) String variables cannot be operated with int variables
c) A string is an object
d) A string can be changed after initializing

(3028) Adapted from Q1, page 21 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: 下面程序段执行后的结果是（）
(The output of the following code is ())

```
String s = new String("abcdefg");

for(int i = 0; i < s.length(); i += 2){
        System.out.print(s.charAt(i));
}
```

a) aceg
b) aCEG

c) abcdefg
d) abcd

28) Given the following Java code snippet:

```
String s = new String("abcdefg");

for(int i = 0; i < s.length(); i++){
    System.out.print(s.charAt(i));
}
```

What is the output?

a) abcdefg
b) bcdefg
c) gfedcba
d) Error

(3029) Adapted from Q1, page 21 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: the same with problem 3028

29) Given the following Java code snippet:

```
String s = new String("abcdefg");

for(int i = s.length() - 1; i >= 0; i-=2){
    System.out.print(s[i]);
}
```

What is the output?

a) abcd
b) geca
c) aceg
d) fdba

(3030) Adapted from Q1, page 21 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: the same with problem 3028

30) Assume we have a string variable, String s = "abcd";
Which of the following is the correct method to return the char 'c'?

a) s[3]
b) s[2]
c) s.charAt(2)
d) s.charAt(3)

(3031) Adapted from Q1, page 21 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: the same with problem 3028

31) Which of String class methods is used to obtain character at specified index?

a) char()
b) Charat()
c) charat()
d) charAt()

(3032) Self-develop
32) Which of the following statements are FALSE?

a) String is a class
b) Strings in java are mutable
c) Every string is an object of class String
d) Java defines a peer class of String, called StringBuffer, which allows a string to be altered

(3033) Self-develop

33) Consider the snippet below. What is the output?

```
String s = "Hello World";
System.out.println(s.charAt(s.toUpperCase().length()));
```

a) d
b) Runtime Exception
c) D
d) H

(3034) Adapted from Q1, page 5 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with problem 3013

34) What will be the output of the below snippet of code?

```
String s1 = "Cat";
String s2 = "Cat";
String s3 = new String("Cat");
System.out.print(s1 == s2);
System.out.print(s1 == s3);
```

a) truefalse
b) truetrue
c) falsefalse
d) falsetrue

(3035) Self-developed

35) A new object is created when a String variable is initialized.

a) True
b) False

(3036) Self-developed

36) Consider the following code,

```
string s=new String();
```

This will create an instance of String with
a) at least one character
b) a default character
c) no characters in it
d) number of characters in it

(3037) Self-developed

37) What will be the output of the following code?

```
String a=new String();
System.Out.Println (“a= ” +a);
```

a) null
b) error
c) =a
d) a=

(3038) Self-developed

38) Given the following code segment, what is in the string referenced by s1?

```
String s1 = "xy";
String s2 = s1;
s1 = s1 + s2 + "z";
```

a) xyxyz
b) xyz
c) zxy
d) z

(3039) Self-developed
39) What is the value of pos after the following code executes?

```
String s1 = "acded cad";
int pos = s1.indexOf("d");
```

a) 2
b) 4
c) 5
d) 8

(3040) Self-developed
40) Which of these classes is the superclass of String and StringBuffer class?
a) java.util
b) java.lang
c) ArrayList
d) None of the above

(3041) Self-developed
41) Which of these operators can be used to concatenate two or more String objects?
a) +
b) +=
c) &
d) ||

(3042) Self-developed
42) Which of these constructors is used to create an empty String object?
a) String( )
b) String(void)
c) String(0)
d) None of the above

(3043) Self-developed
43) What will be the output of the following Java program?

```
class String_demo
{
    public static void main(String args[ ])
    {
            char chars[ ] = {'a','b', 'c'};
            String s = new String(chars);
            System.out.println(s);
     }
}
```

a) a
b) b
c) c
d) abc

(3044) Self-developed
44) In the following Java code, which code fragment should be inserted at line 3 so that the output will be: “123abc 123abc”?

```
StringBuilder sb1 = new StringBuilder("123");
String s1 = "123";
// insert code here
System.out.println(sb1 + " " + s1);
```

a) sb1.append(“abc”); s1.append(“abc”);
b) sb1.append(“abc”); s1.concat(“abc”);
c) sb1.concat(“abc”); s1.append(“abc”);
d) sb1.append(“abc”); s1 = s1.concat(“abc”);

A.3 Control flow

(4001) Self-developed

1) Which of the following is NOT the keyword in Java control flow?
   a) if
   b) elif
   c) while
   d) continue

(4002) Self-developed

2) Which of the following expressions can not be a loop condition in Java?
   a) i > 0
   b) i++
   c) i == 1
   d) bEqual = str.equals('q')

(4003) Self-developed

3) What is the output of the following Java code snippet?

```
int i = 10;
while(i > 0){
    i++;
    if(i == 10){
        break;
    }
}
```

   a) The loop will run for 10 times
   b) Infinite loop
   c) The loop will run for once
   d) The loop will not run

(4004) Self-developed

4) What is the output of the following Java code snippet?

```
for( int i = 0; ; ){

    System.out.println(i++);
    break;

}
```

   a) Infinite loop
   b) Syntax error
   c) 0
   d) None

(4005) Self-developed

5) What is the output of the following Java code snippet?

```
int i = 0;

do{
    if (i % 2 == 0){
        i = i + 2;
    }
}while(i < 7);

System.out.println(i);
```

   a) 4
   b) 6
   c) 8
   d) 10

(4006) Self-developed

6) Which of the following is **TRUE** about “for loops” in Java?

a) We can have more than one statements in the loop body
b) For loops only work for the situation that the number of loops has been determined
c) For loops cannot be implemented by while loops
d) The for loops execute the statements in the loop body first, and then execute the condition

(4007) Self-developed

7) Given the following Java code snippet:

```
String s1 = “hello”;

if (s1 == “hello”){

    System.out.println(“s1 == hello”)
}
else{

    System.out.println(“s1 != hello”)
}
```

What is the output of the above code snippet?

a) s1 == hello
b) s1 != hello
c) Error
d) Nothing happens

(4008) Translated from Q1, page 7 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 关于选择结构下列哪个说法是正确的？ ()
(Which of the following statements is TRUE?())

a) if语句和else语句必须成对出现
(if statement must appear in pairs with the else statement)
b) if语句可以没有else语句对应
(if statement can appear without the else statement)
c) switch结构中每个case语句中必须用break语句
(Each case statement in a switch structure must have break statements)
d) switch结构中必须有default语句
(A switch structure must have default statements)

8) Which of the following statements is TRUE?

a) The if statement must appear in pairs with the else statement
b) The if statement can appear without the else statement
c) Each case statement in a switch structure must have break statements
d) A switch structure must have default statements

(4009) Translated from Q2, page 8 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: while循环和do...while循环的区别是:
(What is the difference between while loops and do...while loops:)

a) 没有区别，这两个结构任何情况下效果一样
(No difference, the two loops are the same thing under all the situation)
b) while循环比do...while循环效率更高
(while loops are more efficient than do...while loops)
c) while循环是先执行后判断，所以循环体至少执行一次
(while loops execute the loop first and then check the loop condition, so the loop body at least execute once)
d) do...while循环是先执行后判断，所以循环体至少执行一次
(do...while loops execute the loop first and then check the loop condition, so the loop body at least execute once)

9) What is the difference between while loops and do...while loops?

a) Same thing
b) while loops are more efficient than do...while loops
c) while loops execute the loop first and then check the loop condition
d) do...while loops execute the loop first and then check the loop condition

(4010) Translated from Q3, page 8 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 关于for循环和while循环的说法哪个正确？ ()

(Which of the following is TRUE about for loops and while loops? ())

a) While循环先判断后执行，for循环先执行后判断
(while loops execute before checking the loop conditions, but for loops do not)
b) While循环判断条件一般是程序结果，for循环判断条件一般是非程序结果
(for loops execute before checking the loop conditions, but while loops do not)
c) 两种循环任何时候都不能被替换
(The two loops cannot be replaced by each other)
d) 两种循环都必须有循环体，循环体不能为空
(The two loops must have a loop body, and the loop body cannot be empty)

10) Which of the following is TRUE about for loops and while loops?

a) while loops execute before checking the loop conditions, but for loops do not
b) for loops execute before checking the loop conditions, but while loops do not
c) for loops can be replaced with or adapted to while loops
d) The two loops must have a loop body

(4011) Translated from Q6, page 15 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: switch语句不能用于下列 ___ 数据类型

(The data type ___ below cannot be used as a condition of a switch structure)

a) byte
b) short
c) char
d) float

11) Which of the following data types cannot be used as a condition of a switch structure?

a) byte
b) float
c) short
d) char

(4012) Adapted from Q9, page 16 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 下面是findSum(int m, int n)方法的定义，方法调用findSum(1, 4)的返回结果是___

(findSum(int m, int n) is defined below. What is the value of findSum(1, 4) ___)

```
int findSum(int m, int n){
        int sum = 0;
        for(int i = m; i <= n; i++){
                sum += i;
        }
        return sum;
}
```

a) 1
b) 4
c) 5
d) 10

12) Given the following Java code snippet:

```
public static int func(int n, int m){

    int sum = 0;
    for(int i = n; i <=m; i++){
        sum += i;
    }

    return sum;
}
```

What is the value of func(1, 3)?

a) 2
b) 4
c) 6
d) 8

(4013) Adapted from Q9, page 16 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with problem 4012

13) Given the following Java code snippet:

```
public static void func(int n, int m){

    for(int i = n; i <=m; i++){
        if(i % 2 == 0){
            System.out.println(i);
        }
    }

}
```

What is the second output of func(1, 6)?

a) 2
b) 4
c) 6
d) 8

(4014) Adapted from Q9, page 16 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with problem 4012

14) Given the following Java code snippet:

```
public static void func(int n, int m){

    for(int i = n; i <=m; i += 2){
        System.out.println(i);
    }

}
```

How many numbers does func(1, 6) output?

a) 2
b) 3
c) 4
d) Error

(4015) Adapted from Q9, page 16 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with problem 4012

15) Given the following Java code snippet:

```
public static int func(int n, int m){

    for(int i = n; i <=m; i++){
        System.out.println(i);
    }

}
```

How many numbers does func(1, 6) output (watch out the method type :))?

a) 2
b) 3

c) 4
d) Error

(4016) Translated from Q21, page 17 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: 下列语句序列执行后，k的值是（）
(Given the following Java code snippet, the value of k is ())

```
int j = 8;
int k = 15;
for(int i = 2; i != j; i += 6){
        k++;
}
```

a) 15
b) 16
c) 17
d) 18

16) Given the following Java code snippet:

```
int j = 8;
int k = 15;

for(int i = 2; i != j; i += 6){
    k++;
}
```

What is the value of k?
a) 15
b) 16
c) 17
d) 18

(4017) Adapted from Q21, page 17 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with problem 4016

17) Given the following Java code snippet:

```
int j = 8;
int k = 8;

for(int i = 2; i == j; i += 6){
    k++;
}
```

What is the value of k?
a) 8
b) 9
c) 10
d) 11

(4018) Adapted from Q21, page 17 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: 下列语句执行后，j的值是（）
(Given the following Java code snippet, the value of j is ())

```
int j = 3;
int i = 2;

while(--i != i / j){
        j += 2;
 }
```

a) 2
b) 4
c) 5
d) 6

18) Given the following Java code snippet:

```
int j = 3;
int i = 2;

while(--i != i / j){
    j += 2;
}
```

What is the value of j?

a) 2
b) 4
c) 5
d) 6

(4019) Adapted from Q21, page 17 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with problem 4018

19) Given the following Java code snippet:

```
int i = 2;
int j = 0;

while(++i == i - j){
    j += 2;
}
```

What is the value of j?

a) 2
b) 4
c) 5
d) 6

(4020) Translated from Q23, page 17 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 下列语句执行后，i的值是（）

(Given the following Java code snippet, the value of i is ())

```
int i = 0;

do{
    i += 3;
}while(i < 10);
```

a) 3
b) 6
c) 12
d) 9

20) Given the following Java code snippet:

```
int i = 0;

do{
    i += 3;
}while(i < 10);
```

What is the value of i?

a) 3

b) 6
c) 12
d) 9

(4021) Adapted from Q23, page 17 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with problem 4020

21) Given the following Java code snippet:

```
int i = 0;

do{
    i += 2;
}while(i % 6 == 0);
```

What is the value of i?
a) 3
b) 6
c) 12
d) 9

(4022) Translated from Q24, page 18 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: 下列语句执行后，k的值是（）
(Given the following Java code snippet, the value of k is ())

```
int i = 6;
int j = 8;
int k = 10;
int n = 5;
int m = 7;

if(!(i < j)){
        k = m + n;
}
else{
        k = m - n;
}
```

a) 12
b) 2
c) -2
d) 10

22) Given the following Java code snippet:

```
int i = 6;
int j = 8;
int k = 10;
int n = 5;
int m = 7;

if(!(i < j)){
    k = m + n;
}
else{
    k = m - n;
}
```

What is the value of k?
a) 12
b) 2
c) -2
d) 10

(4023) Adapted from Q24, page 18 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with problem 4022

23) Given the following Java code snippet:

```
int i = 1;
int j = 2;
int k = 3;
int n = 4;
int m = 5;

if(!(i < j)){
    k = m * n;
}
else{
    k = m / n;
}
```

What is the value of k?

a) 20
b) 3
c) 1
d) 10

(4024) Translated from Q25, page 17 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 下列语句执行后，k的值是（）

(Given the following Java code snippet, the value of k is())

```
int x = 3;
int y = 5;
int k = 0;

switch(x % y + 3){
        case 0:
                k = x * y;
                break;
        case 6:
                k = x / y;
                break;
        case 12:
                k = x - y;
                break;
        default:
                k = x * y - x;
                break;
}
```

What is the value of k?

a) 12
b) 0
c) 15
d) -2

(4025) Adapted from Q25, page 17 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with problem 4024

25) Given the following Java code snippet:

```
int x = 3;
int y = 5;
int k = 2;

switch(x * y - 3){
    case 0:
```

```
                k += x * y;
                break;
        case 6:
                k += x / y;
                break;
        case 12:
                k += y - x;
                break;
        default:
                k = x * y - x;
                break;
}
```

What is the value of k?

a) 17
b) 4
c) 0
d) 12

(4026) Adapted from Q26, page 18 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 执行完下面的程序段后，输出的结果是（）
(Given the following Java code snippet, the output is ())

```
char c = '\0';

for(c = 'a'; c < 'z'; c += 3){
        if(c >= 'd'){
                break;
        }
}

System.out.println("\'" + c + "\'");
```

What is the output of the above code snippet?

a) ‘e’
b) ‘f’
c) ‘d’
d) ‘a’

26) Given the following Java code snippet:

```
char c = '\0';
```

```
for(c = 'a'; c < 'z'; c += 3){
    if(c >= 'd'){
        break;
    }
}

System.out.println(c);
```

What is the output of the above code snippet?

a) e
b) f
c) d
d) a

(4027) Adapted from Q26, page 18 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: the same with problem 4026

27) Given the following Java code snippet:

```
char c = '\0';

for(c = 'a'; c < 'z'; c += 1){
    if(c >= 'd'){
        c += 2;
        break;
    }
}

System.out.println(c);
```

What is the output of the above code snippet?

a) e
b) f
c) d
d) a

(4028) Adapted from Q27, page 18 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: 执行完下面的程序段后，k的值是（）

(Given the following Java code snippet, the value of k is())

```
int k = 0;

label: for(int i = 1; i < 10; i++){
        for(int j = 1; j < 5; j++){
                k += i + j;
                if(j == 3){
                    break label;
        }
 }
```

a) 3
b) 9
c) 12
d) 6

28) Given the following Java code snippet:

```
int k = 0;

for(int i = 1; i < 3; i++){
    for(int j = 1; j < 3; j++){
            k += i + j;
    }
}
```

```
System.out.println(k);
```

What is the output of the above code snippet?
a) 3
b) 5
c) 7
d) 12

(4029) Adapted from Q27, page 18 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with 4028

29) Given the following Java code snippet:

```
int k = 0;

for(int i = 1; i < 3; i++){
    for(int j = 1; j < 3; j++){
        if(i == 2){
            continue;
        }
        k += i + j;

    }
}

System.out.println(k);
```

What is the output of the above code snippet?
a) 3
b) 5
c) 7
d) 12

(4030) Adapted from Q27, page 18 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with 4028

30) Given the following Java code snippet:

```
int k = 0;

for(int i = 1; i < 3; i++){
    for(int j = 1; j < 3; j++){
        if(i == 1){
            break;
        }
        k += i + j;
    }
}

System.out.println(k);
```

What is the output of the above code snippet?
a) 3
b) 5
c) 7
d) 12

(4031) Adapted from Q20, page 42 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: 下列循环语句的循环次数是（）
(The number of the loop executing in the following code is ())

```
int i = 5;

do{
```

```
            System.out.println(i--);
            i--;
        }while(i != 0);
```

a) 5
b) 无限 (infinite)
c) 0
d) 1

31) Given the following Java code snippet:

```
int i = 5;

do{
    i--;
}while(i != 0);
```

How many times will the loop execute?
a) 3
b) 4
c) 5
d) Infinite loop

(4032) Adapted from Q20, page 42 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with 4031
32) Given the following Java code snippet:

```
int i = 5;

do{
    i--;
}while(i != 0);
```

How many times will the loop execute?
a) 3
b) 4
c) 5
d) Infinite loop

(4032) Adapted from Q20, page 42 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with 4031
32) Given the following Java code snippet:

```
int i = 5;

do{
    System.out.println(i--);
    i--;
}while(i != 0);
```

How many times will the loop execute?
a) 3
b) 4
c) 5
d) Infinite loop

(4033) Adapted from Q2, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 写出以下程序的输出结果___
(write down the output of the following program)

```
int j = 2;
switch(j){
   case 2:
         System.out.println(“Value is two.”);
   case 2+1:
         System.out.println(“Value is three.”);
         Break;
   default:
         System.out.println(“Value is ” + j);
         Break;
}
```

33) Given the following Java code snippet:

```
int x = 0;
int y = 4;

if(x > 0){
    if(y > 3){
       System.out.println(“One”);
    }
    else{
       System.out.println(“Two”);
    }
}
else{
      System.out.println(“Three”);
}
```

What is the output of the code?

a) One
b) Two
c) Three
d) Error

(4034) Adapted from Q2, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with 4033

34) Given the following Java code snippet:

```
int x = 1;
int y = 2;

if(x > 0){
   if(y > 3){
     System.out.println(“One”);
   }
 else{
     System.out.println(“Two”);
 }
}
else{
     System.out.println(“Three”);
}
```

What is the output of the code?

a) One
b) Two
c) Three
d) Error

(4035) Adapted from Q2, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with 4033

35) Given the following Java code snippet:

```
int j = 2;
switch(j){
    case 2:
        System.out.println(“The value is two”);
    case 2+1:
        System.out.println(“The value is three”);
        break;
    default:
        System.out.println(“The value is ” + j);
        break;
}
```

What is the output?

a) The value is two
   The value is three

b) The value is three
   The value is 2

c) The value is two
   The value is 2

d) The value is 2

(4036) Adapted from Q2, page 22 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with 4033

36) Given the following Java code snippet:

```
int i = 1;
switch(i){
    case 1:
        System.out.println(“The value is one”);
        break;
    case 1+1:
        System.out.println(“The value is two”);
        break;
    default:
        System.out.println(“The value is ” + i);
        break;
}
```

What is the output?

a) The value is one
b) The value is two
c) The value is 1
d) Error

(4037) Adapted from Q5, page 11 in “《JAVA Programming》Final Exam Questions and Answers”, 2019, Baidu Library [2]

Original: 下面的代码执行后，count的值是什么（）

(Given the following code, the value of count is ())

```
int count = 1;

for(int i = 1; i <= 5; i++){
    count += i;
}

System.out.println(count);
```

a) 5

b) 1
c) 15
d) 16

37) Given the following Java code snippet:

```
int count = 1;
for(int i = 1; i <= 3; i++){
    count += i;
}
System.out.println(count);
```

What is the value of count?
a) 3
b) 5
c) 7
d) 9

(4038) Adapted from Q5, page 11 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: the same with 4037

38) Given the following Java code snippet:

```
int count = 1;
for(int i = 1; i <= 3; i++){
    if(i % 3 == 0){
        count += i;
    }
}
System.out.println(count);
```

What is the value of count?
a) 1
b) 4
c) 6
d) 8

(4039) Adapted from Q11, page 12 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: 以下程序段的输出结果是（）
(the output of the following code is ())

```
int x = 5;
int y = 6;
int z = 4;

boolean b = (x + y > z && x + z > y && y + z > x)
if(b){
        System.out.println("三角形")
}
else{
        System.out.println("不是三角形")
}
```

39) Given the following Java code snippet:

```
int x = 1;
int y = 2;
int z = 3;

boolean b = (x + y > z && x + z > y && y + z > x)
if(b){
    System.out.println("This is a triangle.")
}
```

```
else{
    System.out.println("This cannot be a triangle.")
}
```

What is the output?

a) This is a triangle.
b) This cannot be a triangle.
c) Null
d) Error

(4040) Adapted from Q12, page 12 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]

Original: 以下程序段的输出结果是 ___

(The output of the following code is ___)

```
int a[ ] = {2, 3, 4, 5, 6};
for(int i = a.length - 1; i >= 0; i--){
        System.out.print(a[i] + "");
}
```

40) Given the following Java code snippet:

```
int a[ ] = {1, 2, 3};
for(int i = a.length - 1; i >= 0; i--){

    System.out.print(a[ i ]);
}
```

What is the output?

a) 123
b) 321
c) Null
d) Error

(4041) Adapted from Q12, page 12 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]

Original: the same with 4040

41) Given the following Java code snippet:

```
int a[ ] = {2, 3, 1};
int i = a.length - 1;
while(i >= 0){
    System.out.print(a[i]);
    i--;
}
```

What is the output?

a) 231
b) 321
c) 132
d) 213

A.4 Array

(5001) Self-developed
1) Pick the correct method to declare a variable array of type Integer:
   a) int[ ] a;
   b) a[ ] int;
   c) a int[ ];
   d) int a;

(5002) Self-developed
2) What is the index of the first element in an array?
   a) 1
   b) array.length()
   c) 0
   d) 2

(5003) Self-developed
3) You can pass a negative number as an array size.
   a) True
   b) False

(5004) Self-developed
4) What is the index of the last element in an array?
   a) array.length()
   b) 0
   c) 1 - array.length()
   d) array.length() - 1

(5005) Self-developed
5) How to create a new array of 50 integers?
   a) int[ ] b = int[50];
   b) int[ ] b = new int[50];
   c) new int[ ] b = int[50];
   d) int[ ] b = b int[50];

(5006) Self-developed
6) You can use Arrays to store values of either primitive types or reference types.
   a) True
   b) False

(5007) Self-developed
7) Which of the following statements is TRUE about copying array variables:
   a) Creates a new array referenced by the copied variable.
   b) Yields two references to the same array
   c) Cannot copy array variables
   d) Deletes the first array and creates a new array

(5008) Self-developed
8) What is the output of the following code?

```
public static void main(String[ ] args){
        int[ ] i = new int[0];
        System.out.println(i[0]);
}
```

   a) 0
   b) i
   c) int[ ] i
   d) ArrayIndexOutOfBoundsException

(5009) Self-developed
9) The size of the array can be changed after defining it.
   a) True
   b) False

(5010) Self-developed
10) A new element can be added to an array by simply appending it to the array.
   a) True
   b) False

(5011) Self-developed
11) Which is the correct method to initialize a multidimensional(2d) array of type Integer?
   a) int [row] [column] a = new int [row] [column];
   b) int [column] [row] a = new int [row] [column];
   c) int [ ] [ ] a = new int [row] [column];
   d) int [ ] [ ] a = new int [column] [row];

(5012) Self-developed
12) Which of the following are legal methods to declare arrays?
   a) int [ ] a;
   b) int a[ ];
   c) None of the above
   d) a) and b)

(5013) Self-developed
13) What is the output of the following main method?

```
public static void main(String[ ] args) {
   int[ ][ ] matrix = {
        {12, 1, 0},
        {1, 12, 0},
        {0, 12, 1}
};
   System.out.println(matrix[1][2]);

}
```

   a) 12
   b) 0
   c) 1
   d) No output

(5014) Self-developed
14) In this code, args is considered to be a/an,

```
public static void main(String[] args)
{
   //some code;
}
```

   a) Class
   b) Integer
   c) Constant
   d) Array

(5015) Self-developed
15) What is the output of the following main method?

```
public static void main(String[ ] args)
{
```

```
    String[ ] vowels = {"a", "e", "i", "o", "u",};
    System.out.println(vowels[1] + vowels[3]);

}
```

a) oe
b) eo
c) ai
d) ia

(5016) Self-developed
16) What is the output of the following code?

```
public static void main(String[ ] args)

{
    String[ ] str = {"a","b","c","d","e"};
    System.out.println(str[5]);
}
```

a) e
b) a
c) ea
d) ArrayIndexOutOfBoundsException

(5017) Adapted from Q6, page 29 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: 应用程序的main方法中有以下语句，则执行后的输出结果为（）
(Assume we have the following code snippet in the main method. The output is ())

```
int []x = {125, 21, 5, 168, 98};
int min = x[0];
for(int i = 1; i < x.length; i++){
  if (x[i] < min){
     min = x[i];
  }
}
System.out.println(min);
```

a) 125
b) 5
c) 98
d) 168

17) What is the purpose of the following Java code snippet?

```
temp = score[0];
for(int index = 1; index < 5; index++){
    if (score[index] > temp){
       temp = score[index];
    }
}
```

a) Find the maximum value
b) Find the minimum value
c) Iterate over the array
d) Error

(5018) Self-developed
18) Which of the following is the correct method for array initializing?
a) Int[ ] a;

b) a = {1, 2, 3};
c) int[ ] a = new int[5]{1, 2, 3};
d) int[ ] a = new int[5];

(5019) Self-developed
19) Which of the following statements is **FALSE** in Java?
a) Arrays should be declared before using
b) An array is an object
c) Array is one of the basic data types in Java
d) The default value of a boolean array is "false"

(5020) Self-developed
20) An array is an object
a) True
b) False

(5021) Adapted from Q10, page 22 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: 应用程序的main方法中有以下语句，则输出的结果是（）
(Assume we have the following code snippet in the main method. What is the output?)

```
int b[ ][ ] = {{1, 1, 1}, {2, 2}, {3}};
int sum = 0;

for(int i = 0; i < b.length; i++){
    for (int j = 0; j < b[ i ].length; j++){
        sum *= b[ i ][ j ];
    }
}

System.out.println("sum=" + sum);
```

a) 32
b) 11
c) 2
d) 3

21) Assume that we have the following code in the main method:

```
int b[ ][ ] = {{1, 1, 1}, {2, 2}, {3}};
int sum = 0;

for(int i = 0; i < b.length; i++){
    for (int j = 0; j < b[ i ].length; j++){
        sum += b[ i ][ j ];
    }
}

System.out.println(sum);
```

What is the output?
a) 10
b) 7
c) 3
d) 6

(5022) Adapted from Q10, page 22 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]

Original: the same with problem 5021

22) Assume that we have the following code in the main method:

```
int b[ ][ ] = {{1, 1, 1}, {2, 2}, {3}};
int sum = 0;

for(int i = 0; i < b.length; i++){
    sum += b[i];
}

System.out.println(sum);
```

What is the output?

a) 10
b) 7
c) 3
d) 6

What is the output?

a) 10
b) 7
c) 3
d) 6

(5023) Translated from Q6, page 3 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: 应用程序的main方法中有以下语句，则执行后的输出结果为（）

(Assume we have the following code snippet in the main method. The output is ())

```
int [ ]x = {125, 21, 5, 168, 98};
int min = x[0];
for(int i = 1; i < x.length; i++){
  if (x[ i ] < min){

     min = x[ i ];
  }
}
System.out.println(min);
```

a) 125
b) 5
c) 98
d) 168

23) Assume that we have the following code in the main method:

```
int[ ] x = {125, 21, 5, 168, 98};
int temp = x[0];

for(int i = 0; i < x.length; i++){
    if(x[ i ] < temp)
       temp = x[ i ];
}

System.out.println(temp);
```

What is the output?

a) 21
b) 168
c) 5
d) 98

(5024) Adapted from Q6 page 3 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: The same with problem 5023

24) Assume that we have the following code in the main method:

```
Int[ ] x = {125, 21, 5, 168, 98};
int temp = x[0];

for(int i = 0; i < x.length; i++){
    if(x[ i ] > temp)
        temp = x[ i ];
}

System.out.println(temp);
```

What is the output?

a) 21

b) 168

c) 5

d) 98

(5025) Adapted from Q6, page 3 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with problem 5023

25) Assume that we have the following code in the main method:

```
int[ ] x = {125, 21, 5, 168, 98};
int temp = x[0];

for(int i = 0; i < x.length; i++){
    if(x[ i ] > temp)
        temp = x[ i ];
}

System.out.println(temp);
```

How many times will the loop execute?

a) 2

b) 3

c) 4

d) 5

(5026) Adapted from Q4, page 4 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 定义如下二维数组b，下面的说法正确的是（）

(Given the 2d array b, which of the following is TRUE())

```
int b[ ][ ] = {{1, 2, 3}, {4, 5}, {6, 7, 8}};
```

a) b.length的值是3 (The value of b.length is 3)

b) b[1].length的值是3 (The value of b.length[1] is 3)

c) b[1][1]的值是5 (The value of b[1][1] is 5)

d) 二维数组b的第一行有3个元素 (The first row of the 2d array b has 3 elements)

26) Given the following array b:

```
int b[ ][ ] = {{1, 2, 3}, {4, 5}, {6, 7, 8}};
```

Which of the following is NOT TRUE?

a) b.length equals to 3
b) b[1][1] equals to 5
c) b[1].length equals to 3
d) The first row of the array b has 3 numbers

(5027) Adapted from Q4, page 4 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: the same with problem 5026

27) Given the following array b:

```
int b[ ][ ] = {{1, 2, 3}, {4, 5}, {6, 7, 8}};
```

Which of the following is true?

a) b.length equals to 2
b) b[2][1] equals to 7
c) b[2].length equals to 2
d) b[1][1] equals to 1

(5028) Adapted from Q7, page 27 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: 设有数组定义int MyIntArray = {10, 20, 30, 40, 50, 60, 70}; 则执行以下几个语句后的输出结果是_____。
(Given the array, int MyIntArray = {10, 20, 30, 40, 50, 60, 70}; what is the output of the following Java code_____)

```
int s = 0;
for(int i = 0; i < myArray.length; i++){
        if(myArray[i] % 2 == 1){
                s += MyIntArray[i];
        }
}
System.out.println(s);
```

28) Given the following Java code snippet:

```
int myArray[ ] = {1, 2, 3, 4, 5};
int temp = 0;
for(int i = 0; i < myArray.length; i++){
    if(myArray[ i ] % 2 == 0){
            temp += myArray[ i ];
    }
}
```

What is the value of temp?

a) 2
b) 4
c) 6
d) 8

(5029) Adapted from Q7, page 27 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: the same with problem 5028

29) Given the following Java code snippet:

```
int myArray[ ] = {2, 4, 6, 8};
int temp = 0;
for(int i = 0; i < myArray.length; i++){
    if(myArray[ i ] % 2 != 0){
            temp += myArray[ i ];
    }
}
```

What is the value of temp?

a) 0
b) 2
c) 4
d) 6

(Given the following Java code, which of the following statements is correct? ())

```
Public class Person{
        Static int arr = new int [5];
        Public static void main(String args[]){
                System.out.println(arr[0]);
        }
}
```

a) 编译时将产生错误 (Error when compiling)
b) 编译时正确，运行 (Compile correctly)
c) 输出零 (Output 0)
d) 输出空 (Output None)

30) Given the following Java code snippet:

```
int arr[ ] = new int[5];
system.out.println(arr[0]);
```

What is the output?
a) 0
b) 1
c) null
d) Error

(5031) Adapted from Q8, page 5 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: the same with 5030

31) Given the following Java code snippet:

```
boolean arr[ ] = new boolean[3];
system.out.println(arr[2]);
```

What is the output?
a) false
b) true
c) 0
d) 1

(5032) Adapted from Q2, page 21 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: 有整型数组，int[ ] x = {12, 35, 8, 7, 2};， 则调用方法Arrays.sort(x)后，数组x中的元素值依次是（）

(Given an integer array, int [ ]x = {12, 35, 8, 7, 2}), what is the order of the elements in x when we call the method Arrays.sort(x))
a) 2 7 8 12 35
b) 12 35 8 7 2
c) 35 12 8 7 2
d) 8 7 12 35 2

32) Given the following Java code snippet:

```
int[ ] x = {12, 35, 8, 7, 2};
System.out.println(Arrays.sort(x));
```

What is the output?
a) [12, 35, 8, 7, 2]

b) [2, 7, 8, 12, 35]
c) [35, 12, 8, 7, 2]
d) [8, 7, 12, 35, 2]

(5033) Adapted from Q6, page 3 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: the same with problem 5023

33) Given the following Java code snippet:

```
int[ ] x = {125, 21, 5, 168, 98};
int temp = x[0];

for(int i = 0; i < x.length; i++){
    if(x[ i ] > temp){
        temp = x[ i ];
    }
}
```

What is the value of temp?
a) 125
b) 98
c) 168
d) 5

(5034) Self-developed
34) Given the following Java code snippet:

```
int[ ] x = {81, 90, 6, 72, 14};
int temp = x[0];
int temp = x[0];

for(int i = x.length - 1; i >= 0; i -= 2){
    if(x[ i ] < temp){
        temp = x[ i ];
    }
}
```

What is the value of temp?
a) 81
b) 6
c) 90
d) 14

(5035) Self-developed
35) What is the output of the following main function?

```
public static void main(String[ ] args)
{
   String[ ] vowels = {"1", "2", "3", "4", "5",};
   System.out.println(vowels[1] + vowels[5]);

}
```

a) 15
b) 25
c) 14
d) ArrayIndexOutOfBounds Exception

(5036) Adapted from Q6, page 3 in “JAVA programming final exam questions”, 2017, Baidu Library [1] Original: the same with problem 5023

36) What is the purpose of the following Java code snippet?

```
temp = score[0];
for(int index = 1; index < 5; index++){
    if (score[index] < temp){
       temp = score[index];
    }
}
```

a) Find the maximum value
b) Find the minimum value
c) Iterate over the array
d) Error

(5037) Self-developed

37) Given the following Java code snippet:

```
int[ ] x = {0, 11,22, 33, 44};
System.out.println(x[x.length-2]);
```

What is the output?
a) 11
b) 22
c) 33
d) 44

(5038) Self-developed

38) Arrays can be multi-dimensional in Java.
a) True
b) False

(5039) Self-developed

39) Is the following declaration TRUE?

```
int y = 56;
int[ ] number = {12, 34, 90, y, 65};
```

a) True
b) False

(5040) Self-developed

40) Arrays can store multiple elements of different data types.
a) True
b) False

(5041) Self-developed

41) Using the correct index, we can fetch data elements of an array at run time.
a) True
b) False

(5042) Self-developed

42) If the array is of an Object type, the default value of the array elements are:
a) null
b) None
c) False
d) None of the above

(5043) Self-developed

43) Which of the following declarations will cause a compile time error?
a) int[ ] scores = null;
b) String[ ] nameArray = {5, 3, 2};
c) int[ ] scoreArray = {50,90,85};
d) String[ ] nameArray = new String[10];

(5044) Self-developed

44) What is returned from arr[3] if arr={6, 3, 1, 2}?
a) 6
b) 3
c) 1
d) 2

(5045) Self-developed
45) Given the following code snippet, what is the output?

```
private int[ ] a = {1, 3, -5, -2};

public void loop()
{
  int amt = 5;
  int i = 0;
  while (i < a.length)
  {
    a[ i ] = a[ i ] * amt;
  }
System.out.println(a);
}
```

a) {5,15,-25,-10}
b) {5,3,-5,-2}
c) {-2,-5,3,1}
d) No output due to infinite loop

(5046) Self-developed
46) What is the output of the following code fragment?

```
int [ ] odd = {1, 3, 5, 7, 9, 11 };
System.out.println( odd[0] + "  " + odd[3] ) ;
```

a) 1 5
b) 6
c) 1 7
d) No output

(5047) Self-developed
47) What is the output of the following code fragment?

```
int [ ] nums = {2, 4, 6, 8, 10};
nums[0] = 44;
nums[4] = nums[2];
System.out.println(nums[0] + "  " + nums[4]);
```

a) 44 6
b) 44 10
c) 2 4
d) 446

(5048) Self-developed
48) What is the length of this array?

```
double[ ] stuff = {1.5,  2.5,  3.5,  4.5,  5.5,  6.5};
```

a) 6
b) 7
c) 5
d) 4

(5049) Self-developed
49) Which code line could possibly "call" this method?

```
public static int SomeMethod(double[ ] array, int[ ] number){
        //somecode
}
```

a) int value = SomeMethod(money, grades);
b) SomeMethod(money, grades);
c) double value = SomeMethod(money, grades);
d) int value = SomeMethod(money);

(5050) Self-developed
50) The length of an array in Java CANNOT be zero
a) True
b) False

(5051) Self-developed
51) If an index value is less than 0 or greater than or equal to 'arrayname'.length in an array element access expression, an ____ is thrown.
a) ArrayOutOfBoundsException
b) ArraysIndexOutOfBoundsException
c) ArrayIndexOutOfBoundsException
d) ArrayIndexIsOutOfBoundsException

(5052) Self-developed
52) The ith element in the array has an index ____
a) i
b) i - 1
c) i + 1
d) None of above

(5053) Self-developed
53) In Java, each array object has a final field named ___ that stores the size of the array.
a) width
b) size
c) length
d) distance

A.5 Classes

(6001) Self-developed
1) What is the keyword for creating a method that can be called without creating any object instances?
a) static
b) final
c) hidden
d) public

(6002) Self-developed
2) An object is an instance of a class.
a) True
b) False

(6003) Self-developed
3) Which of the following is a wrapper class in Java?
a) int
b) Integer
c) double
d) None of the above

(6004) Adapted from Q4, page 35 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: 下列修饰符中与访问控制无关的是（）
(Which of the following is NOT an access control modifier ())
a) private
b) public
c) protected
d) final

4) Which of the following is NOT an access modifier for members of a class?
   a) public
   b) private
   c) protected
   d) None of the above

(6005) Self-developed
5) An object has:
   a) Behavior
   b) State
   c) Identity
   d) All of the above

(6006) Self-developed
6) Which of the following keywords is used for creating objects in Java?
   a) create
   b) instanceOf
   c) return
   d) New

(6007) Adapted from Q4, page 35 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]
Original: the same with problem 7004

7) Which of the following keywords are used to declare that a field cannot change? (Base 4)
   a) final
   b) private
   c) static
   d) None of the above

(6008) Self-developed
8) While calling a method, the arguments have to be passed in the same order as defined in the method.
   a) True
   b) False

(6009) Self-developed
9) The keyword is used to declare that only one field is needed per class.
   a) public
   b) private
   c) static
   d) None of the above

(6010) Self-developed
10) Math.pow(a,b) computes a raised to the power b, this happens by:
   a) Calling the static method pow() in the Math class
   b) Creating an object of type Math and then calling the method pow()
   c) No methods are called
   d) None of the above

(6011) Self-developed
11) A method can mutate objects.
   a) True
   b) False

(6012) Self-developed
12) A void method can return a value.
   a) True
   b) False

(6013) Self-developed
13) When you pass a parameter to a method, which of the following is true:
   a) The method can change the value of the variable
   b) Call by value is used where the method gets copies of the argument values
   c) None of the above
   d) a) and b)

(6014) Self-developed

14) In a public class, you can access which of the following:

a) Class
b) Method
c) Field
d) All of the above

(6015) Self-developed

15) Encapsulation is a concept in Object Oriented Programming for combining properties and methods of an object in a single unit.

a) True
b) False

(6016) Self-developed

16) What is the correct way to call a method of a class?

a) Class_name.method_name();
b) Class_name method_name();
c) method_name();
d) Class_name(method_name);

(6017) Self-developed

17) An abstract class need not have one or more abstract methods.

a) True
b) False

(6018) Self-developed

18) What are the instance variables in the following code:

```
public class IdentifyMyParts {
   public static int x = 7;
   public int y = 3;
}
```

a) x
b) y
c) x and y
d) None of the above

(6019) Self-developed

19) What are the class variables in the following code:

```
public class IdentifyMyParts {
   public static int x = 7;
   public int y = 3;
}
```

a) x
b) y
c) x and y
d) None of the above

(6020) Self-developed

20) Which of the following statements is **TRUE** in Java?

a) An instance method can directly call the instance method of the super class
b) An instance method can directly call a super class method
c) An instance method can directly call methods of other classes
d) An instance method can directly call methods of the current class

(6021) Translated from Q10, page 10 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: 关于方法main()的说法哪一个是正确的？ ()
(Which of the following statements is TRUE about the main() method)

a) 方法main()只能放在公共类中
(the main() method can only be placed in a public class)
b) main()的头定义可以根据情况任意更改
(the definition of the main() can be changed based on different situations)
c) 一个类中可以没有main()方法
(there can be no main() method in a class)
d) 所有对象的创建都必须在main()方法中
(objects must be created in the main() method)

21) Which of the following statements is **TRUE** in Java?
a) A class can have more than one main methods
b) The main method must be included in a class
c) The name of the main method must be the same as the .java filename
d) If there is only one statement in the main method, {} can be not used

(6022) Self-developed
22) Which of the following statements is **TRUE** for object-oriented programming?
a) Classes simulate entities in the real world
b) We should create as many classes as there are entities
c) Entities in the real world cannot be described by classes
d) The behavior and attributes of the object are encapsulated in the class and the outside obtains it by calling the method of the class

(6023) Self-developed
23) How many constructor method(s) are there in the following Java class?

```
public class Test{
    private int x;

    public Test(){
      x = 35;
    }

    public void Test(double f){

      this.x = (int)f;

    }

    public Test(String s){}
}
```

a) 0
b) 1
c) 2
d) 3

(6024) Adapted from Q11, page 9 in “JAVA programming final exam questions”, 2017, Baidu Library [1]
Original: 构造函数何时被调用？ ()
(When will the constructor method be called?)
a) 创建对象时 (when creating an object)
b) 类定义时 (when defining a class)
c) 使用对象方法时 (when using the methods of an object)
d) 使用对象属性时 (when using the attributes of an object)

24) Which of the following is **TRUE** about constructor methods in Java?
a) Constructor methods will be automatically created by the compiler
b) We must manually declare constructor methods in Java
c) The code still can run without declaring constructor methods, therefore, constructor methods are not necessary for Java classes
d) We can only have one constructor method in a Java class

(6025) Self-developed
25) Given the following Java code snippet:

```
class Test{

    private int m;

    public static void fun(){

            \\ some code
    }
}
```

What should we do if we want the member variable m to be directly accessed by the function fun()?

a) Change the statement “private int m” to “protected int m”
b) Change the statement “private int m” to “public int m”
c) Change the statement “private int m” to “static int m”
d) Change the statement “private int m” to “int m”

(6026) Self-developed
26) Given the following Java code snippet:

```
class Test{

    public int m;

    public static void fun(){

            \\ some code
    }
}
```

The member variable m can be directly accessed by the function fun()

a) True
b) False

(6027) Self-developed
27) What is the output for the following Java code snippet?

```
public class Test{

    string x = “1”;
    int y;

    public static void main(String args[]){

            int z = 2;
            system.out.println(“x+y+z”);
    }
}
```

a) 3
b) 102
c) 12
d) Error

(6028) Self-developed
28) What is the output for the following Java code snippet?

```
public class Test{

    public static void main(String args[]){

            String x = “1”;
            int y = 2;
            int z = 3;
            system.out.println(“x+y+z”);
    }
}
```

a) 123
b) 3
c) 5
d) Error

(6029) Adapted from Q1, page 3 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: 下面哪些关键字能用来控制对类成员的访问？ ()
(Which of the following keywords can control the access to members of a class?)

a) public
b) protected
c) private
d) Default

29) Which of the following keywords CANNOT control the access to members of a class?
a) private
b) public
c) default
d) protected

(6030) Adapted from Q1, page 3 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with problem 6029

30) Which of the following is NOT an access control modifier?
a) private
b) final
c) protected
d) public

(6031) Adapted from Q5, page 9 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: void的含义（）
(What is the meaning of void?)

a) 方法没有返回值 (the method does not return value)
b) 方法体为空 (the method body is empty)
c) 没有意义 (no meaning)
d) 定义方法时必须使用 (must be used when we define methods)

31) Which of the following is TRUE about the **void** modifier?
a) void methods are empty methods, having no statements in the body
b) void methods have no meaning
c) void methods do not return values
d) void methods are used when we define methods

(6032) Translated from Q11, page 9 in “JAVA programming final exam questions”, 2017, Baidu Library [1]

Original: the same with problem 6024

32) When will the constructor methods be called?
a) When we define a class
b) When we use the attributes of an object
c) When we create an object
d) When we use the methods of an object

(6033) Self-developed

33) The keyword **this** cannot be used in a static method
a) True
b) False

(6034) Self-developed

34) The keyword **this** stands for an object of the current class
a) True
b) False

(6035) Self-developed

35) Which of the following is TRUE about the keyword **this**?

a) **this** can be used in a static method
b) **this** can be used in the main method
c) **this** is an object of the current class
d) **this** cannot access member variables

(6036) Self-developed

36) What is the type of the main method in Java?

a) void
b) int
c) String
d) float

(6037) Translated from Q34, page 20 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: 下面哪些选项是正确的main()方法说明?
(Which of the following is the correct main() method?)

a) void main()
b) private static void main(String args[ ])
c) public main(String args[ ])
d) public static void main(String args[ ])

37) Which of the following is the correct main method in Java?

a) void main( )
b) private static void main(String args[ ])
c) public static void main(String args[ ])
d) public void main(String args[ ])

(6038) Adapted from Q31, page 18 in "JAVA programming final exam questions", 2017, Baidu Library [1]

Original: 下面关于Java Application程序结构特点描述中，错误的是（）
(Which of the following statements is FALSE about Java Application())

a) 一个Java Application程序由一个或多个文件组成，每个文件可以定义一个或多个类，每个类由若干个方法和变量组成
(A Java Application is comprised of one or more files, and each file can define one or more classes, and each class is comprised of one or more methods and variables)
b) Java程序中声明有public类时，则Java程序文件名必须与public类的类名相同，并区分大小写，扩展名为.java
(In a Java program, the name of .java file must be the same as that of the public class, and it is case-sensitive)
c) 组成Java Application程序的多个类中，有且仅有一个主类
(There can only be one main method in a Java program)
d) 一个.java文件定义多个类时，允许其中声明多个public类
(We can declare more than one public class in a .java file)

38) Which of the following statements is FALSE about Java programs?

a) There can only be one main method in a Java program
b) The name of the public class in a Java program must be the same as the name of the .java file
c) We can have more than one public class in a Java program
d) A Java class is comprised of methods and variables

(6039) Self-developed

39) The correct way to declare a public constant variable "pi" in a Java class is:

a) public double int pi = 3.14;
b) public final double pi = 3.14;
c) final public double pi = 3.14;
d) final double pi = 3.14;

(6040) Adapted from Q1, page 13 in “《JAVA Programming》Final Exam Questions and Answers”, 2019, Baidu Library [2]

Original: 以下程序的输出结果为___

(The output of the following program is ___)

```
public class Person{
        String name;
        int age;

        public University(String name, int age){
                this.name = name;
                this.age = age;
         }

        public static void main(String[] args){
                Person c = new Person(“Peter”, 17);
                System.out.println(c.name + “ is ” + c.age + “ years old.”);
        }
}
```

40) Given the following Java code snippet:

```
public class University{
    String name;
    int age;

    public University(String name, int age){
            this.name = name;
            this.age = age;
    }

    public static void main(String[] args){
            University u = new University(“Purdue”, 152);
            System.out.println(u.name + “ is ” + u.age + “ years old.”);
    }
}
```

What is the output?

a) is years old.
b) Purdue 152
c) Purdue is 152 years old.
d) Error

(6041) Adapted from Q3, page 14 in “《JAVA Programming》Final Exam Questions and Answers”, 2019, Baidu Library [2]

Original: 以下程序的输出结果为___

(The output of the following program is ___)

```
public class Tom{
        private static String name;
        private float weight;

        public void setweight(float weight){
                this.weight = weight;
        }
        public void out(){
                System.out.println(name + “weight: ” + weight);
        }

        public static void main(String[] args){
                Tom.name = “汤姆猫”;
                Tom cat = new Tom();
                cat.setweight(20);
                cat.out();
        }
}
```

41) Given the following Java code snippet:

```
public class Cat{
    private static String name;
    private float weight;

    public void setweight(float weight){
        this.weight = weight;
    }

    public void out(){
        System.out.println(name + “weight: ” + weight);
    }

    public static void main(String[ ] args){
        Cat.name = “Tom”;
        Cat Tom = new Cat();
        Tom.setweight(20);
        Tom.out();
    }
}
```

What is the output?

a) weight:
b) weight: 20
c) Tom weight: 20
d) Error

(6042) Adapted from Q1, page 17 in “《JAVA Programming》Final Exam Questions and Answers”, 2019, Baidu Library [2]

Original: 按要求编写以下程序:

(Implement the following program as required:)

1）创建一个Rectangle类，添加width和height两个成员变量
(Create a Rectangle class, adding two members called width and height)

2）在Rectangle类中添加两个方法分别计算周长和面积
(Create two methods to calculate the perimeter and the area in the Rectangle class)

3）编程利用Rectangle输出一个矩形的周长和面积
(Output the perimeter and the area of a rectangle)

```
public class Rectangle{
    float width, height;

    public Rectangle(float width, float height){
        this.width = width;
        this.height = height;
    }

    public float getLength(float width, float height){
        return (this.width + this.height) * 2;
    }

    public float getArea(float width, float height){
        return this.width * this.height;
    }

    public static void main(String[] args){
        Rectangle rect = new Rectangle(10, 20);
        System.out.println(“周长是：” + rec.getLength());
        System.out.println(“面积是：” + rect.getArea());
    }
}
```

42) Given the following Java code snippet:

```
public class Rectangle{
    float width, height;

    public Rectangle(float width, float height){
        this.width = width;
        this.height = height;
    }
    public float getArea(float width, float height){
        return this.width * this.height;
    }

    public static void main(String[] args){
        Rectangle rec = new Rectangle(5, 5);
        System.out.println(rec.getArea());
    }
}
```

What is the output?

a) 5
b) 10
c) 25
d) Error

(6043) Adapted from Q12, page 23 in "《JAVA Programming》Final Exam Questions and Answers", 2019, Baidu Library [2]

Original: 程序Test.java编译运行后输出的结果为（）
(What is the output of Test.java())

```
public Test{
    String s1 = "Java";
    public static void main(String[ ] args){
        int z = "1.8";
        Test t = new Test();
        System.out.println(t.s1 + ' ' + z);
    }
}
```

a) java2
b) 2
c) 没有输出结果 (No output)
d) java

43) Given the following Java code snippet:

```
public Test{
    String s1 = "Java";
    public static void main(String[ ] args){
        int z = "1.8";
        Test t = new Test();
        System.out.println(t.s1 + ' ' + z);

    }
}
```

What is the output?

a) Java
b) Java 1.8
c) 1.8
d) Error

(6044) Self-developed
44) In the Java programming language, the code is placed inside ___.
a) Classes, Interfaces
b) Methods
c) Blocks
d) All the above

(6045) Self-developed
45) A Class in Java is like a ____.
a) Prototype
b) Instruction Sheet
c) Blueprint
d) All the above

(6046) Self-developed
46) In Java, the keyword used to declare a class is ___.
a) Class
b) Java
c) class
d) java

(6047) Self-developed
47) A Java class can contain___.
a) Variables
b) Methods, Constructors
c) Inner Classes (A class inside another class)
d) All the above

(6048) Self-developed
48) An object is created at __ time in Java.
a) Compile-time
b) Run time
c) Assembling time
d) None of the above

(6047) Self-developed
47) A Java class can contain___.
a) Variables
b) Methods, Constructors
c) Inner Classes (A class inside another class)
d) All the above

(6048) Self-developed
48) An object is created at __ time in Java.
a) Compile-time
b) Run time
c) Assembling time
d) None of the above

(6049) Self-developed
49) Choose the correct statement about the main method in Java.
a) The main method is not a required method
b) The main method must be declared public static void
c) You can define program flow using the main method and the Java virtual machine calls the main method directly.
d) All the above

(6050) Self-developed
50) Creating an object from a class is also called ____.
a) Initializing
b) Instantiating
c) Interfacing
d) None of the above

(6051) Self-developed
51) The default value of a static integer variable of a class in Java is,

a) 0
b) 1
c) Null
d) None of the above

(6052) Self-developed
52) Which of the following is a valid declaration of an object of class Box?

a) Box obj = new Box();
b) Box obj = new Box;
c) obj = new Box( );
d) new Box obj;