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JUNE 22 - 26, 2020 #ASEEVC
Paper ID #31614

Work in Progress: Students Find Active Learning Beneficial in Intro Programming Course

Dr. Tonya Whitehead, Wayne State University

Dr. Tonya Whitehead is Associate Director of the Office for Teaching and Learning and Adjunct Faculty in the College of Engineering at Wayne State University. At the Office for Teaching and Learning, she focuses on STEM Pedagogy and teaching development programs for graduate students. Supported by the WSU WIDER program, she has implemented several evidence-based pedagogies in her basic engineering courses. These efforts led to her being honored with the 2017 Garrett T. Heberlein Endowment Award for Excellence in Teaching. Dr. Whitehead began her training as an instructor while a King-Chavez-Parks Future Faculty Fellow, by attending active learning and problem based learning boot camps at Lawrence Technological University. She earned her PhD in Biomedical Engineering at Wayne State University. Before coming to Wayne State she received a Master of Science in Manufacturing and Engineering Management and a Bachelor of Science in Computer Engineering at Michigan State University. She is an active member of the Professional and Organizational Development (POD) Network, International Consortium for Education Development (ICED), American Society of Engineering Education (ASEE), Biomedical Engineering Society (BMES), Society for Women Engineers (SWE), and Tau Beta Pi, Engineering Honor Society.

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Introduction

The Introduction to Programming and Computation at Wayne State University (WSU), which is a required foundational course in MATLAB taken by six different engineering majors, was not perceived well by students, which affected engineering retention. At the onset of the course, many students were apprehensive about the material. From discussions with students, we learned that a number of students did not see connections between this course and courses in their major, or the usefulness of the material in their future careers. Beginning in Fall 2016 several pedagogical changes were incorporated into the course. The full study collected student data to see the effects each aspect had on different student groups. This work in progress paper will examine the student's perceptions of course structure and support based on their demographic information.

Prior to this study, the course was taught in 70-100 person sections primarily in a lecture style. Topics in the course were only vaguely connected to their chosen disciple and thus students would struggle to find the benefit in the course. Many students had never programmed before and found the thought process completely foreign. As has been seen at other universities, this contributed to students' lack of engagement and dissatisfaction [1].

Females and minorities are chronically underrepresented in engineering [2] and industry is continually calling for additional engineers [3, 4]. Extensive research has been done on ways to increase student engagement and success in STEM fields [5-7]. The 2012 President's Council of Advisors on Science and Technology report Engage to Excel lists these as strongly supported practices: small group discussion and peer instruction, testing, one-minute papers, clickers, problem-based learning, case studies, analytical challenges before lectures, group tests, problem sets in groups, concept mapping, writing with peer review, computer simulations and games, and combinations of active learning methods [8]. Studies have shown that female engineering students cite the availability of external support and group work as supporting their success [9]. We capitalized on that foundation by incorporating a wide range of active learning strategies into an entry-level class creating a more interactive environment to support all students' success.

In addition to the classroom environment, student motivations and perceptions can affect outcomes for programming courses. Previous work has been done on several student factors. Initial motivation, goal orientation, and instrumentality were studied by Shell et al as contributing factors [10]. Bergin and Reilly reported on the role of intrinsic and extrinsic motivations and self-efficacy in learning programming [11]. Duckworth has reviewed the role of grit and self-control [12]. Data was collected in this study related to these topics, retention, and achievement of learning outcomes and is currently being analyzed for future papers.

Project Approach & Experimental Methods

Overall Project Structure

The study started as part of an internal grant from the NSF-funded grant initiative at our institution to increase evidence-based teaching practices in STEM courses. It implemented several active learning strategies to improve student satisfaction and engagement in an entry-level MATLAB programming course. The tools were implemented in all sections of the course, each taught by a different instructor. Materials were shared across sections to provide as similar an experience as possible, however in-class delivery varied somewhat.

The course improvement started with the implementation of a self-directed, student-centered final group coding project that replaced two existing rigid individual projects. Following the initial introduction of the project, other pedagogical changes were also incorporated to improve student motivation and outcomes. A flipped classroom model was implemented, where students watch videos or do readings prior to class focused on syntax and programming structure, then practice what they learned during class time [13]. To ensure that students were completing the pre-class work, initially online just-in-time (JiT) quizzes were used to analyze student understanding. After two semesters students were very dissatisfied with those quizzes, so they were replaced with study guides to provide scaffolding to students as they watched the videos. Due to the large class size, Peer Mentors (PM) and Teaching Assistants (TA) were incorporated into the classroom to ensure that all student questions were answered and to provide peer-assisted instruction [14]. A classroom response system was added to gather real-time data on student understanding of the underlying concepts in the course [15]. Outside of classes students also had access to a PM or TA for the course at the STEM Commons, a science and engineering group study area. All of these tools worked together to increase classroom engagement. Klingbeil has shown that a similar structure for teaching engineering math using MATLAB improved student retention [16].

Data collection and analysis

Starting in Fall 2017 students were asked to agree to participate in the study by a researcher that was not their instructor and the instructor was not notified of who participated until after the course ended. Students that agreed to participate allowed their survey results, course work, and grades to be included in the study. All study procedures were approved by the WSU's Institutional Review Board. Student surveys were conducted as part of the normal course requirements at the beginning and the end of the semester. After the course was completed and grades were submitted informed consent forms were provided to the instructor. Student survey responses and course outcomes were combined using their student ID number, which was then removed. Only students that completed all study components were included in the analysis.

The beginning of the semester surveys included student demographic information, a self-assessment of engineering skills, and the GRIT-S questionnaire [17]. The end of semester survey included the intrinsic motivation activity perception questionnaire for computer programming, a repeat of the engineering skills assessment, rating for how much students felt different aspects of the course benefited them and additional questions about their perceptions of the self-directed project. To determine students' feelings on the aspects of the course they were asked: "What effect did each of the following things have on your understanding of the concepts in this class?" The students rated each item from Extremely Negatively (-3) to Extremely Positively (3). The seven-point Likert scale was selected to allow students to indicate both positive and negative perceptions so that we could better separate the benefits and challenges that students experienced. Median, mode, mean and standard deviation were calculated for each item.

Course Component Details

This section provides a brief explanation of each of the course components that the students were asked to rank.

Exam Review Sessions

These optional sessions were led by TAs or PMs working through problems like those that would appear on exams. Leaders focused on the thought process and breaking down questions to determine what was being asked.

Tutoring Desk

WSU has a dedicated space, the STEM Commons, for STEM peer mentors to meet with student, or for students to work in self-assembled groups. This course had either a TA or PM available in this area to answer questions and help students work through problems during all open hours (M -Th 9-9; F 9-5). Students could choose to utilize this resource as they needed.

Peer Mentors (In-Class)

During a portion of class time, the students would work with their assigned groups on problems relating to the day's topics. PMs and TAs would assist the instructor to answer questions and check in with all the groups to ensure that the students were understanding the concept and making progress on the problems.

Assigned Groups

After the end of the second week of the class, students were placed in groups for the remainder of the semester. CATME was used to create the student groups [18]. Students were sorted primarily based on schedules to allow outside of class meetings. Additionally, the system was set to not outnumber underrepresented students within a group and to group students of different GPAs together [19]. Keeping groups for a long period allows the students to develop through the stages of small group development [20].

Project

The new final project was first introduced as a pilot in Fall 2016 in all three sections of the course. Each instructor structured the process differently. Feedback from students and the results from the various sections informed updates to the project that was then repiloted in Winter 2017 [21]. The final version allowed students to select any data set that is readily available on the internet as long as it has at least 10,000 data points. The students were encouraged to choose data that interested their team and related to their future work.

Online Quizzes

These were multiple choice, fill in the blank, or calculation questions that were scored automatically. The students took the quizzes at home in a 3-day window while being recorded to ensure academic integrity. In Fall 2017 and Winter 2018 each weekly quiz included an online component in addition to an in-class component (described below). Based on student feedback about workload, the quizzes were changed to alternate between online and in-class starting in Fall 2018.

In-class Quizzes

These consisted of a question or two that involved creating code in MATLAB to solve the problem. Students completed them in class on their own computers while being monitored by the instructor and other support personnel (PMs/TAs).

Study Guides

Short worksheets were provided to lead the student through the assigned videos or readings for each class session. They were turned in for participation, but not graded for accuracy. These were used for Fall 2018 and Winter 2019 after the JiT quizzes were discontinued.

Weekly Homework

Assignment sets were turned in for grades. Some problems were worked on as exercises during class, however the majority of the work was done outside class.

Polling Questions

During class, the iClicker system was used to gather students' responses to multiple choice questions. Generally, they were focused on pointing out areas where students most often make mistakes. Studies have shown that requiring students to select an answer, even if it's incorrect, helps improve retention [15].

In-class Exercises

Questions were used to allow students to practice concepts during class. Students worked with their assigned groups to complete the problems with assistance from the instructor, PMs and TAs. They were not collected or scored.

Instructor-led Examples

The instructor worked through problems to help students understand the thought process. The students were encouraged to participate in the process by suggesting solutions.

Just-In-Time (JiT) Quizzes

Quizzes were due just prior to each class session and covered the topics discussed in pre-readings and videos. Scores were given for participation.

Required Videos

The flipped portion of the class mostly relied on videos to introduce MATLAB syntax. Existing YouTube videos on the topic were selected and assigned. Students were expected to watch the videos, work through the examples, and come to class with a basic understanding of the tool.

Lectures

Short presentations in PowerPoint format primarily focused on areas where students often struggled with a topic.

Results and Discussion

Active learning has been shown repeatedly to improve student outcomes and satisfaction [5-7]. In this study, several active learning strategies and support tools were implemented to improve student success. The breakdown of sections of the course that were included in the study can be found in Table 1. We will look at the student results across all sections for this paper.

Table 1. Course summary for the semesters included in the study

Semester	Section	Instructor	Students Enrolled	Study Participants	%
Fall 2017	A - 001	Instructor 1	96	41	42.71%
	B - 004	Instructor 2	63	23	36.51%
Winter 2018	C - 001	Instructor 2	43	16	37.21%
	D - 002	Instructor 1	91	39	42.86%
Fall 2018	E - 002	Instructor 2	45	15	33.33%
	F - 003	Instructor 3	40	9	22.50%
	G - 004	Instructor 1	66	20	30.30%
Winter 2019	H - 001	Instructor 2	26	7	26.92%
	I - 002	Instructor 1	71	31	43.66%
	J - 003	Instructor 4	21	4	19.05%
		TOTAL	**562**	**205**	**36.48%**

When the study started each section had capacity for 70-100 students. In later semesters additional sections were added to lower the total students per sections. This was partially due to construction on campus changing the availability of large computer labs that were required for exams.

Figure 1 shows the percentage of students that responded with each effect level for all aspects of the course. The course project shows the most students indicating that it had some positive effect on their understanding with 86.36%, followed closely by weekly homework (85.31%), in-class exercises (84.66%), and instructor-led examples (83.62%). These results support the idea that practice is essential for understanding and mastering computer programming. The first three of these items required the student to practice the material individually or with a group. The final one was an excellent opportunity for the student to learn more about the thought process of breaking down the problem. The instructor would guide the students to the answer, while actively involving them in the decision-making process. This indicates that these items should continue to be used in this course.

Figure 1 also shows items that student felt negatively impacted their understanding. The items with the highest negative impact responses included online quizzes (26.86%), JiT quizzes (24.73%), and study guides (23.81%). The JiT quizzes were only used in the first two semesters and then replaced by study guides due to students' negative responses. Both the JiT quizzes and study guides were used in the flipped portion of the course: students did not have instructor support while working on either. JiT quizzes and study guides were also required when students

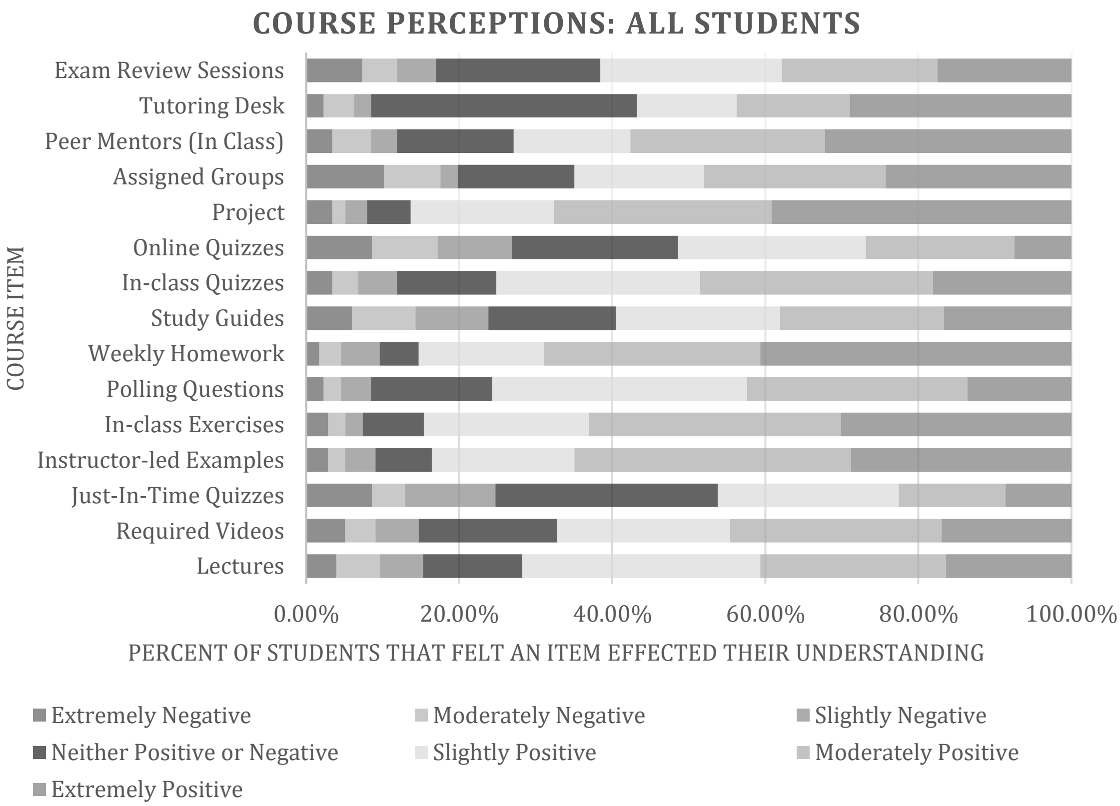

Figure 1. How students perceive the effect of each item on student understanding in the course. A table of the exact percentages is included in Appendix A.

were presented with the material for the first time, which could make them more frustrating. The online quizzing environment has received negative feedback in written assessments and could be a contributing factor to the negative impact indicated here. These results indicate the need to reconsider using these tools in the course or the need to provide more information to the students about their purpose. The study guides were intended to be a tool for the students and a formative assessment of their understanding prior to class. All of these were low-stakes items.

Another interesting subset of items in this figure is those that had a low negative impact percentage, but which did not fall in the top of the positive impact items. Polling questions (positive 75.71% / negative 8.47%) gave the students an opportunity in class to check their understanding. The questions were also structured as discussion points: as a follow-up to the questions, the instructor and students would discuss why the other possible answers were incorrect or theorize when they could be correct. The other was the tutoring desk (positive 56.82% / negative 8.52%). The lower positive score was likely due to it being optional, which is also evident in it’s very high (34.66%) neutral rating. Having the smallest negative percentage is a very strong indicator of the benefit that students see in this support piece, making it a vital part of the course structure.

Additional information can be gathered by looking at the students in demographic subgroups: one of the challenges in early engineering courses is supporting underrepresented groups. The data is further broken down in Table 2 to examine the degree to which these groups benefited from each aspect of the course. Each cell in the table shows the median, mode, mean, and standard deviation of the scores for that subgroup.

Male students were the largest demographic subgroup in the study. They indicated that the project was most beneficial for them and the online quizzes were the least. This agrees with the aggregated data for all students, likely since they make up over half of the students included. Females, which are an underrepresented group in engineering, making up just 30% of the enrollment at WSU, found the weekly homework more beneficial than the project. They also

Table 2. Demographic breakdown of students' perception of the effect of course items. Scores range from extremely positive (3) to extremely negative (-3)

Median (Mode) Mean ± Std. Dev	**Male N=110**	**Female N=67**	**White N=97**	**Black N=9**	**Asian N=31**	**Hispanic N=19**	**Other N=8**
Exam Review Sessions	1 (0) 0.74±1.67	1 (2) 0.93±1.74	1 (1) 0.88±1.55	2 (2) 0.67±2.55	1 (2) 0.90±1.87	1 (1) 0.58±1.57	1 (1) 1.25±1.16
Tutoring Desk	1 (0) 1.12±1.48	1 (3) 1.13±1.71	1 (0) 1.14±1.50	2 (2) 1.67±1.87	1 (0) 0.90±1.68	1 (0) 1.16±1.54	1 (0) 0.75±1.67
Peer Mentors (In Class)	2 (3) 1.38±1.69	2 (3) 1.40±1.57	2 (3) 1.41±1.61	2 (3) 1.33±1.94	2 (3) 1.45±1.79	2 (2) 1.21±1.62	2 (3) 1.00±1.85
Assigned Groups	2 (2) 1.07±1.84	1 (3) 0.61±2.07	1 (2) 0.81±1.86	0 (0) 0.00±2.35	2 (3) 1.39±1.94	2 (2) 1.37±1.64	2 (3) 0.88±2.10
Project	2 (3) ▲ 1.94±1.27	2 (3) 1.48±1.72	2 (3) 1.77±1.40	2 (2) 1.22±1.86	2 (3) ▲ 2.00±1.34	2 (3) 1.58±1.68	2 (2) 1.63±2.00
Online Quizzes	0 (1) ▼ 0.17±1.69	1 (2) 0.59±1.64	0 (1) 0.29±1.69	1 (1) 0.33±1.94	1 (1) 0.55±1.63	0 (0) 0.32±1.57	1 (3) 0.75±1.83
In-class Quizzes	1 (1) 1.24±1.39	2 (2) 1.13±1.61	2 (2) 1.35±1.38	1 (2) 0.56±2.07	1 (1) 1.06±1.46	1 (1) 1.05±1.39	2 (2) 1.25±1.67
Study Guides*	1 (2) 0.65±1.88	1 (1) 0.77±1.59	1 (1) 0.57±1.84	1 (0) 1.00±1.00	2 (2) 1.15±1.69	1 (1) ▼ 0.14±1.68	1 (1) 1.00±1.63
Weekly Homework	2 (3) 1.75±1.45	2 (3) ▲ 1.87±1.43	2 (3) ▲ 2.04±1.17	2 (2) 0.78±1.99	2 (2) 1.23±1.69	2 (3) ▲ 2.11±1.05	2 (3) 1.50±1.69
Polling Questions	1 (1) 1.09±1.34	1 (1) 1.28±1.23	1 (1) 1.15±1.27	1 (2) 1.11±1.27	1 (1) 1.13±1.48	1 (2) 1.42±0.90	2 (2) 1.63±0.92
In-class Exercises	2 (2) 1.53±1.44	2 (3) 1.78±1.35	2 (2) 1.65±1.39	2 (3) 1.33±2.06	2 (3) 1.61±1.61	2 (2) 1.84±0.76	2 (3) 1.75±1.39
Instructor-led Examples	2 (2) 1.57±1.45	2 (2) 1.66±1.41	2 (2) 1.56±1.47	2 (2) 1.56±1.81	2 (3) 1.71±1.40	2 (2) 2.05±0.78	2 (3) ▲ 1.88±1.36
Just-In-Time Quizzes*	0 (0) 0.21±1.52	1 (0) ▼ 0.50±1.76	0 (0) ▼ 0.26±1.56	0 (0) ▼ -0.50±1.73	1 (1) ▼ 0.36±1.80	2 (2) 0.83±1.53	1 (1) 1.25±1.26
Required Videos	1 (2) 0.95±1.07	1 (1) 1.07±1.51	1 (2) 0.97±0.83	2 (1) ▲ 1.78±0.83	1 (2) 0.94±1.84	2 (2) 1.42±1.30	1 (1) ▼ 0.50±1.31
Lectures	1 (1) 0.98±1.52	1 (1) 1.03±1.61	1 (1) 0.88±1.53	1 (1) 0.44±2.07	1 (1) 1.06±1.61	2 (2) 1.26±1.41	2 (2) 1.75±1.28

▲ Highest mean in column; ▼Lowest mean in column; * used for 2 of the 4 semesters.

rated the assigned groups as having minimal benefit. This may indicate that the group structure of the project had a negative effect on perceptions of the project itself. Research has shown that females can be overshadowed in group settings when paired with their male counterparts [22, 23]. Groups were set up to minimize females being outnumbered, however, that doesn't always happen. Additional follow-up is needed with the students to better understand what is leading to the lower perceived benefit of project score for females.

Hispanic students indicated that weekly homework was the most beneficial, giving it the highest score in the table. They also rated instructor-led examples extremely high and above the group project. These were also the highest items for the full student group.

Black students indicated that they received the most benefit from the required videos, which no other groups rated as high. Benefits to recorded lecture material have been reported to include the ability for students to view and revisit the material whenever it is convenient for them [24]. This may include while commuting or late at night for students with family and work commitments outside of school. Additionally, they can return to the material to review if something isn't clear. Black students also rated the tutoring desk as more beneficial than any other group. Individualized support could be particularly beneficial for this group.

The presented preliminary analysis indicated that most of the course elements were perceived as beneficial by the students, especially, those that involved hands-on practice such as examples, exercises, and the open-ended project. Peer mentors and polling questions were also perceived as positive on average across demographic groups. The slightly lower score may be due to students' resistance to active learning formats [25]. The largely positive responses to the course structure support the plan to continue with this overall template. However, some results warrant adjustments: as mentioned JiT quizzes were already replaced. Assigned groups were rated in the bottom three for both female and black students. This could mean that more care is needed in creating groups, or additional support is needed for developing group cohesiveness.

This paper presented a small subset of the data collected in the study; much more work is left to be done. Ongoing analysis will look at other student aspects such as grit, intrinsic motivation, and final grades, as an indicator of student outcomes, to see if there are perception differences among these groups. Consistency across instructors will also be examined. While not included in the original data collection, separating first-generation students could provide some additional insight into the course structure. Retention data for these groups could also be examined in comparison to groups before the changes were implemented.

Acknowledgments

This study is part of grant activities funded by NSF Grant 1524878 Evaluation of Use of Evidence-Based Methods in STEM Instruction. Kristina Lenn contributed to preparation of the research proposal for the sub-award that supported this effort. Several people have contributed to the development of the course and materials: Jeffrey Potoff PhD, Marcis Jansons PhD, Diana Diaz, Loren Schwiebert PhD, Douglas Harriman, Elizabeth Steel PhD, Javad Roostaei PhD, and Xiaoyu Chen, as well as, numerous student assistants.

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Appendix A

Table 3: Percent values for each group displayed in Figure 1

ALL STUDENTS	Extremely Negative	Moderately Negative	Slightly Negative	Neither Positive or Negative	Slightly Positive	Moderately Positive	Extremely Positive
Lectures	3.95%	5.65%	5.65%	12.99%	31.07%	24.29%	16.38%
Required Videos	5.08%	3.95%	5.65%	18.08%	22.60%	27.68%	16.95%
Just-In-Time Quizzes	8.60%	4.30%	11.83%	29.03%	23.66%	13.98%	8.60%
Instructor lead Examples	2.82%	2.26%	3.95%	7.34%	18.64%	36.16%	28.81%
In-class Exercises	2.84%	2.27%	2.27%	7.95%	21.59%	32.95%	30.11%
Polling (Clicker) Questions	2.26%	2.26%	3.95%	15.82%	33.33%	28.81%	13.56%
Weekly Homework	1.69%	2.82%	5.08%	5.08%	16.38%	28.25%	40.68%
Study Guides	5.95%	8.33%	9.52%	16.67%	21.43%	21.43%	16.67%
In-class Quizzes	3.39%	3.39%	5.08%	12.99%	26.55%	30.51%	18.08%
Online Quizzes	8.57%	8.57%	9.71%	21.71%	24.57%	19.43%	7.43%
Project	3.41%	1.70%	2.84%	5.68%	18.75%	28.41%	39.20%
Assigned Groups	10.17%	7.34%	2.26%	15.25%	16.95%	23.73%	24.29%
Peer Mentors (In Class)	3.39%	5.08%	3.39%	15.25%	15.25%	25.42%	32.20%
Tutoring Desk	2.27%	3.98%	2.27%	34.66%	13.07%	14.77%	28.98%
Exam Review Sessions	7.34%	4.52%	5.08%	21.47%	23.73%	20.34%	17.51%