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Studying High School Students' Technical Thinking

Narantuya M. [1], **Enkh-Amgalan D** [2]

[1]Ph.D, National University of Mongolia, School of Sciences, Department of Education and Psychology

[2]Officer at the Education Evaluation Center

Abstract: ***This study aims at evaluating to what extend the technical thinkingof secondary school studentsevolving, analyzing some factors of students' learning. Out of 37,207 high schoolstudents in the2015-2016 academic year, 9.4% or 3,395 students participated in this study. The results showed mid-levels of technical competenceamong these students. The first assumption to prove was the reliability of the Bennett's methods in studying the technical competence of students approved. The second assumption is the importance of teaching methods and forms of learning in the development of technical thinking of students. The results of the study confirmed reliability of the Bennett's methods in assessing technical thinking of students. However, performance of "static" tasks was very low, there were no differences between learning in both ordinary and advanced groups, which indicate a need for substantial reviewof teaching methods and curriculum for advanced classes.***

Keywords: technical thinking, learning factors, physics

1. Introduction

In the 21st century, one of the moving factors of the society and countrywere that the main objectives in the classroom curriculum has become to create one's ability to develop independently and to increase one's desire to acquire new techniques and technologies(Батдорж.Г., 1999).The concept of human capital was originated from Schultz's "Investment in Human Capital", published in the American Economic Review in 1961. Schultz believed that human capital consisted of technology, experience, and knowledge.Known researchers, organizations and management consulting firms however, believe that the key performance indicators for human capital should be the following the same as how Wah (1999)Edvinsson& Malone (1999) takes employee productivity, company investment in training, employee education and credentials, professional background and years of working experience. Theconcept of a knowledge-based economy has been developed based on the concept of human capital theory, whichcounts skillful citizens as social wealth and a big economic factor. This is a concept about social potential to creatively employ, renew and redesign our own resources. Thus, it brought up in the society a main focus on modern employees,a working force with high technological education, and a young generation with a creative mind.

The concept of linking education with industry and technology, developing communicational technology skills and creating a young generation developed high order thinking skills (HOTS)has been taken as a key policy and changes have been made in relation with the educational content, standards, and programs(Bloom.B., 2000).HOTS have been widely studied in various fields of study such as humanities, sciences, and business. The key findings of these studies show that there are 1) various definitions of HOTS and that these definitions vary among scholars, practitioners, learners, and educators (Anderson & Krathwohl, 2001; Bloom & Krathwohl, 1956; Marzano, 2000; Wiggins & McTighe, 2005); 2) various instructional strategies used to enhance HOTS among students and how these strategies are not only used by educators to enhance HOTS among their students, but are also employed by students themselves for the same purpose (Chinedu, Kamin, & Olabiyi, 2015; Miri, Ben-Chaim, & Uri, 2007); and 3) various factors that affect HOTS among students such as demographics, motivation, classroom environment, psychological and intellectual characteristics (Budsankom, Tatsirin, Sawangboon, Damrongpanit, & CHuensirimongkol, 2015). The key findings of the studies in the fields also show that HOTS are often discussed in relation to critical thinking (Norris & Ennis, 1989), academic achievement and development (Beachboard & Beachboard, 2010), graduate attributes (Thomas, 2011), ICT in education (McMahon, 2009), and how demographics and other factors may or may not affect HOTS and the types of instructional strategies used to enhance them among students (Budsankom et al., 2015) (Collin Jerome, Julia Ai-Cheng Lee,Su-Hie Ting , 2017).

The education of Mathematics, the natural sciences and home economics plays an important role in developing students' technical thinking. Therefore, in this research work, we studied and made an assessment for high school students' technical thinking skills by using theBennett's test. The assessment aims at determining the high school's students' technical thinking level, and its contributing factors.

The *goal* of the study was to assess the high school students' current level of technical thinking

Objectives

1) Study and assess theories and concepts about creative thinking and technical thinking skills
2) Assess secondary school 12th grade students' technical thinking skills with Bennett method
3) Analyze teaching and learning in the physics' classes in terms of developing technical thinking in students by observing both advanced and regular program classes
4) Making analysis on secondary school factors in developing technical thinking in students
5) Develop guideline based on theresults of the research

"Thinking is an intricate process directed at understanding the essence, inner law, relations, and characteristics of things. With thinking, it is possible to learn about things in a practical and abstract way".Scholars have been studying about the creative, critical, and logical sides of thinking;trying to study and define creative thinking from many perspectives, including the understanding of a given idea, discovering its hidden meaning and unclear points, comparing it with other ideas,verifying it with actual facts, and therefore, based on these points, a person can express his or her idea independently (Нарантуяа.М., 2012).

Definition and viewpoints by scholars
- Torrance (1965;1966;1988)"Creative thinking is a skill to sense the issue, propose assumptions and new ideas and discuss the outcome".
- Torrance (1988, 2000), Tayor and Sackes (1981) stated "Creative thinking is given to everyone and it can be developed through training".
- John Dewey, when he first defined "creative thinking as reflective thinking", he explained that "a thinking that evaluates approach to study belief and knowledge, in other words, the truth closely and actively".

Over twenty years ago, empirical research comparing lecture methods versus discussion techniques was summarized in the report: Teaching and Learning in the Classroom: A Review of the Research Literature prepared by the National Center for Research to Improve Postsecondary Teaching and Learning (McKeachie, et al., 1987). The review concluded that "In those experiments involving measures of retention of information after the end of a course, measures of problem solving, thinking, attitude change, or motivation for further learning, the results tend to show differences favoring discussion methods over lecture‖" (p. 70). To cite some additional large-scale, high-quality research studies:

Hake (1998) reported the results of one study involving 62 introductory physics courses (N>6000 students). Compared to traditional lecture-based instruction, instructional approaches that promoted interactive engagement produced dramatic student gains in conceptual and problem-solving test scores. Springer et al. (1998) similarly reported a large meta-analysis of studies examining small group learning in SMET courses (i.e., Science, Math, Engineering, and Technology). Compared to traditional lecture-based instructions, various forms of small group learning produced higher test scores, more positive attitudes of students, and higher levels of student persistence. Knight & Wood (2005), in an article titled ―Teaching More by Lecturing Less,‖ reported the results of a study completed in a large, upper-division Biology lecture course. When compared to students' performance when the course was taught using a traditional lecture format, students who were taught with (a) in-class activities in place of some lecture time, (b) collaborative work in student groups, and (c) increased in-class formative assessment and (d) group discussion were observed to make significantly higher learning gains and better conceptual understanding.

Possessing creative and critical thinking, the following skills for solving problem are acquired. They includeimproving, modeling, modifying, finding another solution, finding good solutions for problems, defining causing links and creating(Жаргалсайхан.Ш, 2010).

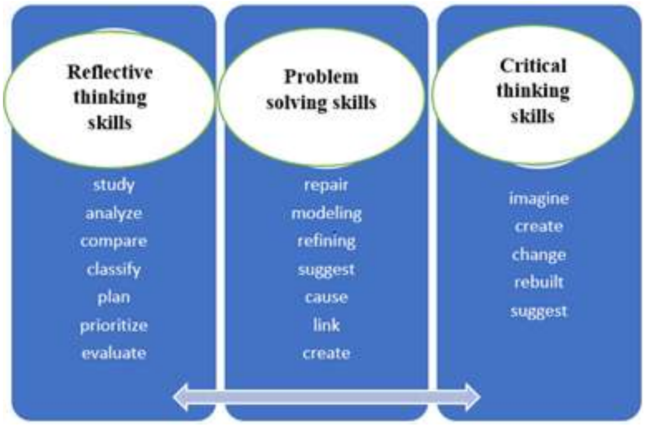

Chart 2: Thinking skills

Technical and technological advancement is the main foundation for increasing possibilities of finding methods and solutions based on technology and developing data systems. It set the foundation for developing the concept of new problem-solving skills and technical thinking skills.

Current state of developing technical thinking in students through physics classes.

"Engaging learners in the excitement of science, helping them discover the value of evidence-based reasoning and higher-order cognitive skills, and teaching them to become creative problem solvers have long been goals of science education reformers"(Zollner.A., 2008). "But the means to achieve these goals, especially methods to promote creative thinking in scientific problem solving, have not become widely known or used" (DeHaan, 2009).Mathematics, engineering and natural science lessons are considered scientific sectors that are most important in developing technical thinking in this new era of innovation and technology. Because these science fields develop technical thinking, they form the following approaches:
- Getting acquainted with objects in nature and environment;
- Realizing the importance of knowledge;
- Having an idea of how to solve a problem;
- Pondering and carrying out a plan;
- Developing and controlling decision processes;
- Evaluating the outcome;
- Concluding the outcome of one own's action.

The education program stated that following complex skills are acquired through high school natural science lessons. The objectives of natural science lessons are that "Through this lesson, students shall become an individual who continuously develop and study his ability to learn objects and events of nature, who is environment-friendly and who contributes to protect it, who has scientific approach to everything and who is eager to learn."(Core program of Natural science, 2015). Today knowledge and skills of high school students who are studying natural science is evaluated by the "Secondary school students and educational quality evaluation manual" approved by theMinister of Education and Science order No. A/309 on Aug. 16, 2013. It states:

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The following should be considered to evaluate knowledge

- Learning facts (concept), definitions and scientific ideas
- Using correct terms (keywords) from the school program for Grade 10-12
- Using and identifying signs, numbers, units and measures studied in Grade 10-12

The following should be considered to evaluate understanding and problem solving skills

- Explaining scientific concepts
- Solving problems using those scientific concepts
- Using knowledge of scientific concepts in familiar and unfamiliar situations
- Calculating and problem solving

The following should be considered to evaluate scientific method

- Making assessments on data using scientific methods such as charts and schemes
- Recognizing and detecting the principles of data
- Drawing conclusions
- Understanding scientific methods(observing, planning, collecting data, surveillance, processing data, introducing data results in a suitable way, analyzing results for conclusion, evaluating experiment)

2. Materials and Methods

A Grade 12 physics lesson program, based on secondary school comprehensive skills, includes practical and technical skills and their qualification; therefore, it shows that the program aims at developing technical thinking. Result of Bennett method for evaluating technical thinking in students.

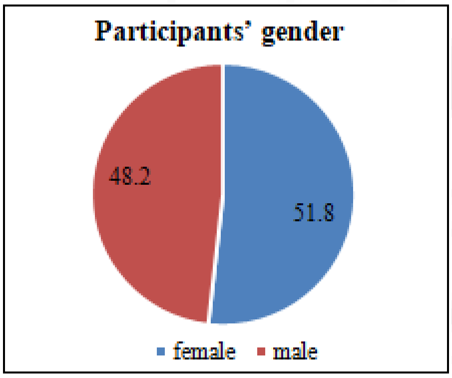


Chart 1: 12 gradestudent, %, by gender

1,593 are male and 1,757 are female students, which means the gender ratio is small .

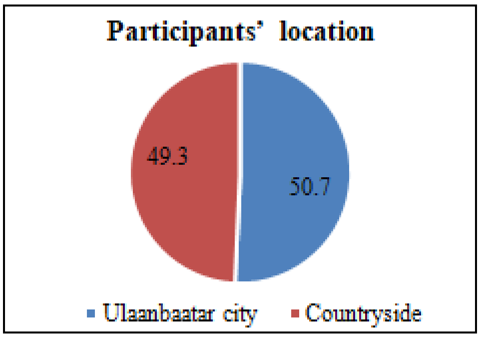


Chart 2: 12 grade students, %, by location

Out of a total of 3,395 students took part in study, 50.7% study in the city and 49.4% study in the rural area.

Table 1: Reliability statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.572	.587	70

When defined,the reliability level of Bennett method for evaluating technical thinking in students, the Chronbach's Alpha coefficient was 0.572, in other words, it's a "questionable" rank, which shows that the Bennett method task had an external influence. (Chart 2) in other words, it was influenced from space, time, and the used method of the exam.

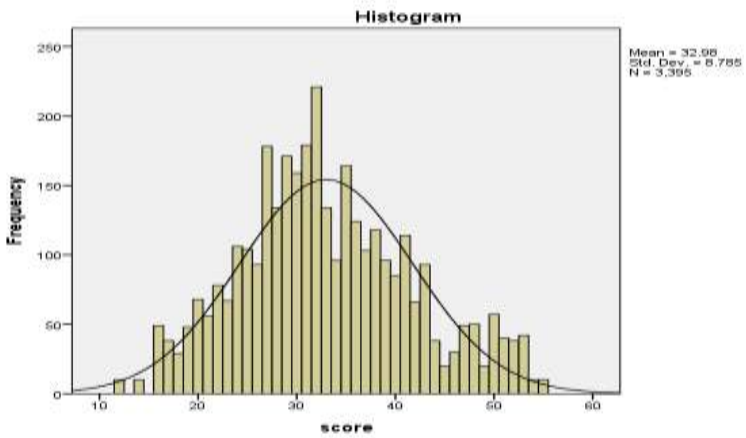


Chart 3: Point distribution evaluating technical thinking (general).

Looking at the score distribution evaluated by Bennett method,the average performance of technical thinking in students is 32.98, thestandard incline is 8.785. The chart shows that students' score is in the center of a normal distribution. It means that the Bennett method for evaluating technical thinking in students is suitable for this purpose. (Chart 6).

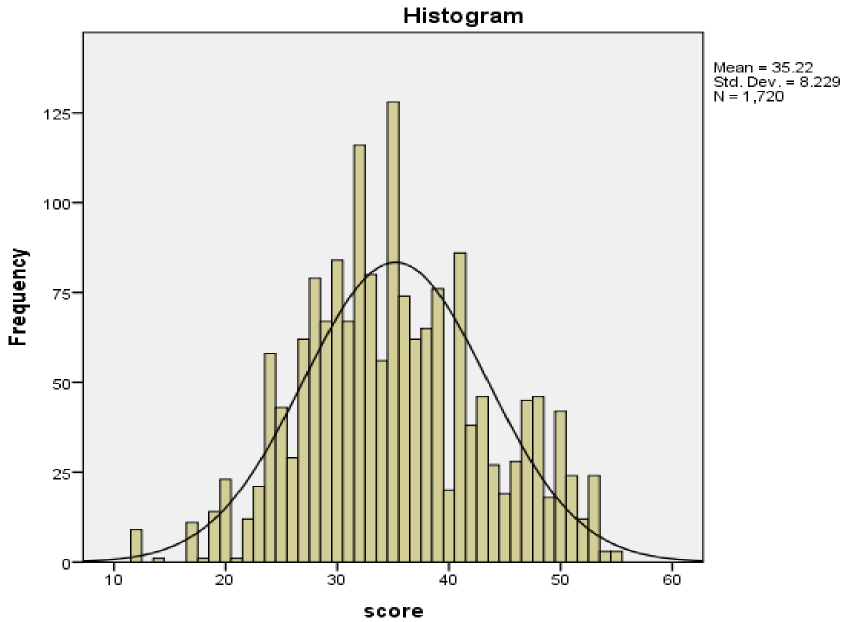


Chart 4: Score distribution for evaluating technical thinking (Ulaanbaatar).

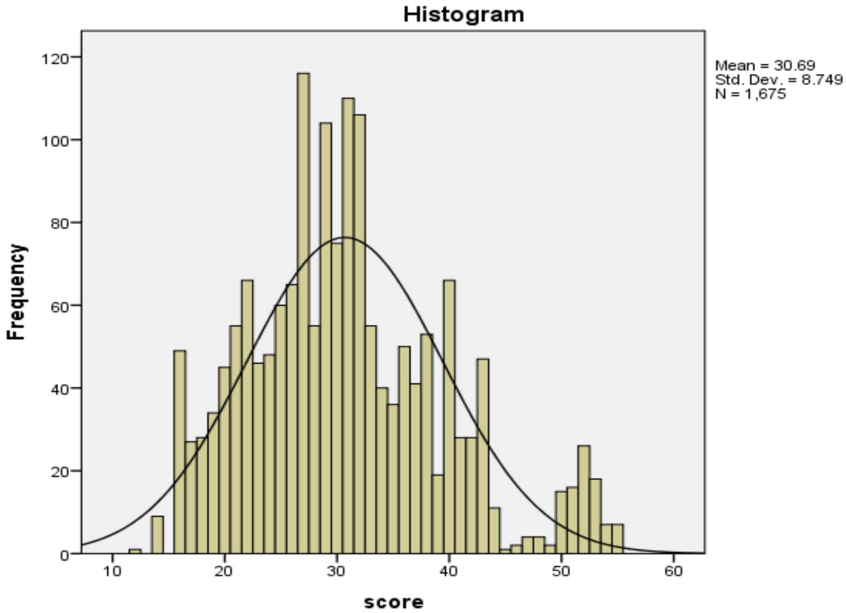


Chart 5: Score distribution for evaluating technical thinking (rural area).

The average performance of technical thinking of 1,720 students living in Ulaanbaatar is 35.22, whilethe standard incline is 8.229 (Chart7). The average performance of technical thinking of the 1,675 students in the rural area is 30.69, while the standard incline is 8.749 байна (Chart 8). It shows the result that the Bennett method is suitable for students in Ulaanbaatar, but harder for students in the rural area. This is probably related to the fact that the environment where the information was received is different for students in the city and in the rural area.

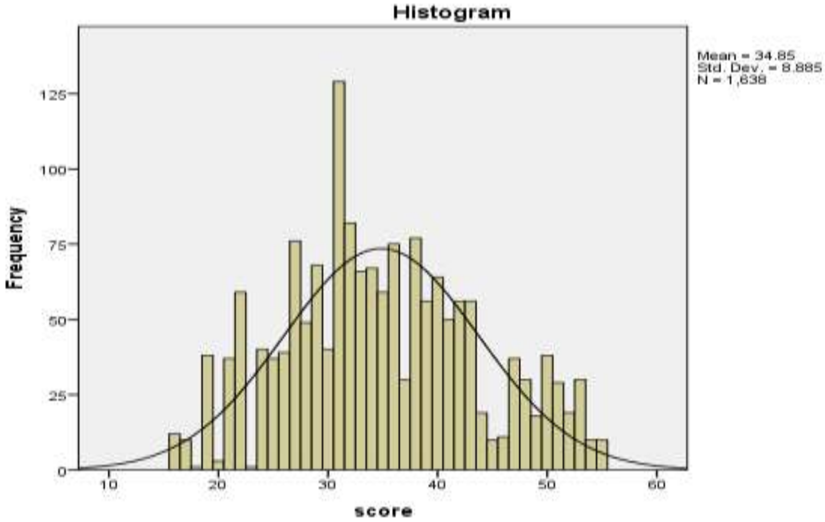


Chart 6: Score distribution of evaluating technical thinking (Male students).

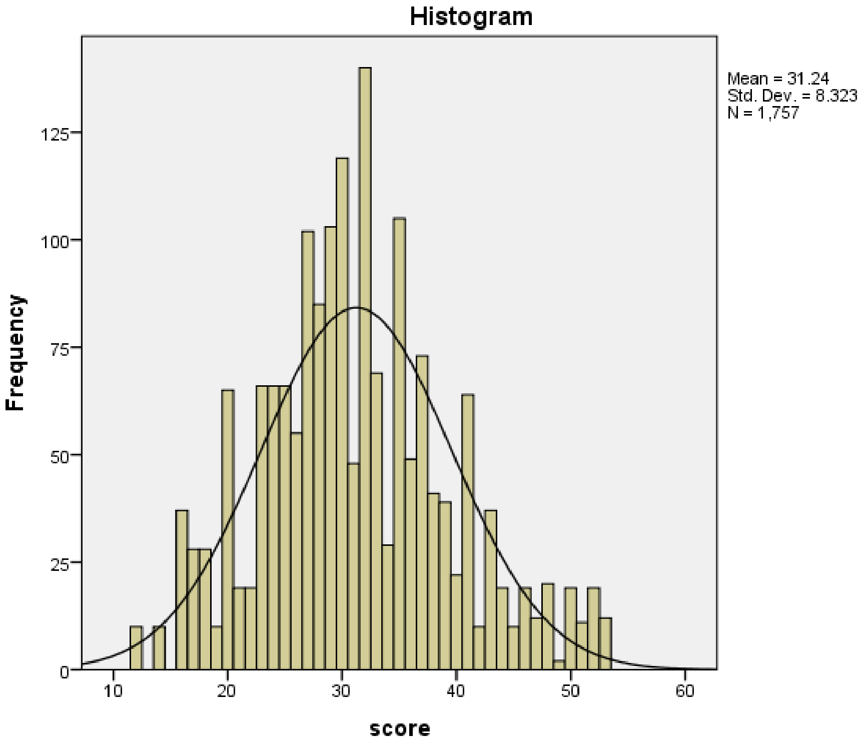


Chart 7: Score distribution of evaluating technical thinking (Male students).

The average score of male students is 34.85, while the standard incline is 8.885(Chart 9). The average score of female students is 31.24, while thestandard incline is 8.323 байна (Chart 10). From the statistics, the average score of male students is higher than the average score of female students.This can be explained by gender dissimilarity. The vision and space perception of boys are more developed than girls. In other words, with exception for the teaching method, there are gender factors influencing technical thinking.

Table 2: Technical thinking indicator (General)

	Number of students	Minimum value	Maximum value	Average	Standard mistake
Score	3395	12	55	32.98	8.785

3. Results

As for the scores, a total of 3,395 students took part in the study and their minimum score was 12, the maximum score was 55, the average value was 32.98 and the standard mistake was 8.785 (Table 3).

Table 3: Technical thinking performance (by gender)

Gender	Students		Bennett method performance for evaluating technical thinking				
	Number	Percentage	Average value	Median	Maximum score	Minimum score	Standard incline
Male	1638	48.2%	34.9	34.0	55.0	16.0	8.9
Female	1757	51.8%	31.2	30.0	53.0	12.0	8.3

For male students, the minimum score was 16, whereas female students got 12, and male students got a maximum score of 55, whereas female students got a 53 (Table 4).It shows that technical thinking in male students is higher than female students.

Table 4: Technical thinking performance (by location)

Performance		Number of students	Average value	Maximum value	Minimum value	Standard incline
City	Male	777	38.9	55	17	8
	Female	943	33.0	53	12	8
Rural area	Male	861	32.7	55	16	9
	Female	814	29.8	53	12	8

For students in the city, male students had a minimum score of 17, female students had 12, themaximum score was 55 for male, 53 for female students, the standard incline 8 respectively, and the average score was 38 for male, 33 for female.

For students in the rural area, male students had a minimum score of 16, female students had 12, the maximum score was 55 for male, 53 for female students, the standard incline for male is 9, female is 8,and the average score was 32 for male, 29for female.

Looking at this data, for male students, city students have slightly higher technical thinking performance, whereas female students don't have adifference.

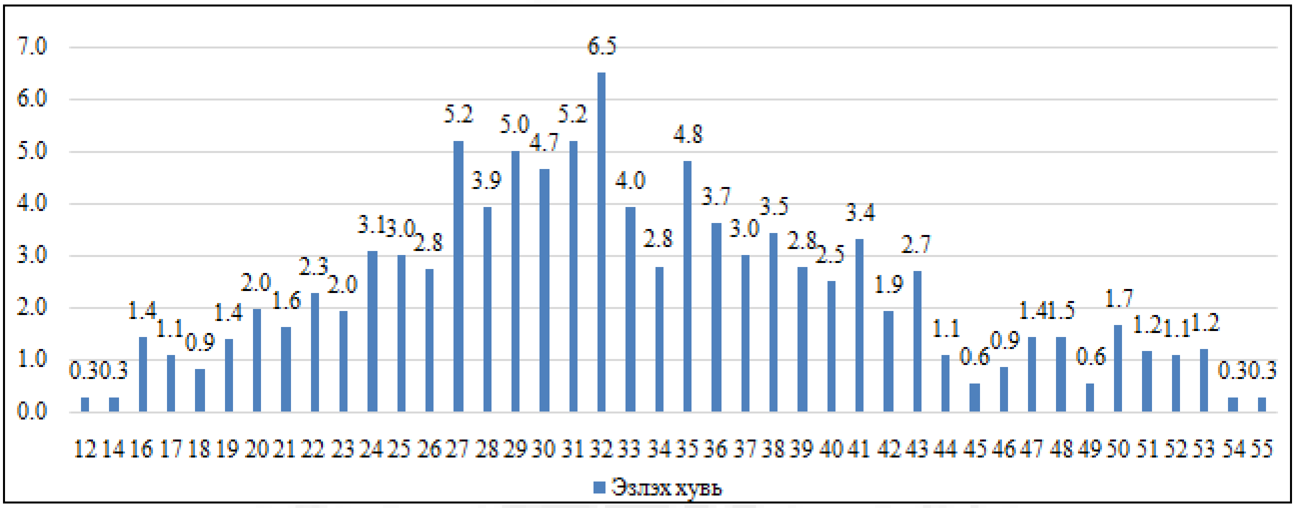


Chart 8: Technical thinking performance (analysis)

0.3% of total students had a minimum score of 12, and 0.3% had a maximum score of 55 (Chart11).

The Bennett evaluation method evaluated the following technical thinking skills.

1) Modifying
2) Finding way out
3) Defining cause links
4) Modeling
5) Creating
6) Fixing, rebuilding

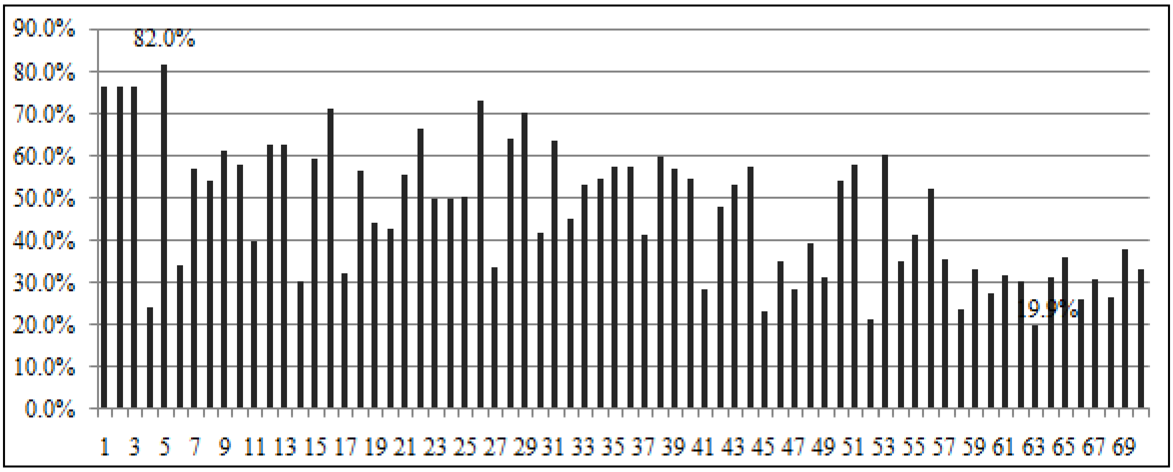


Chart 9: Bennett test performance (by question)

Analyzing the performance on each problem of the Bennett methodshows that the average performance of total of 70 problems is 47.18 percent, with Problem 5 having the highest performance rate (82%) and Problem 63 having the lowest performance rate (19.9%). It will be clearer if skills to solve problems 5 and 63 is integrated into the above Bennett test skills.

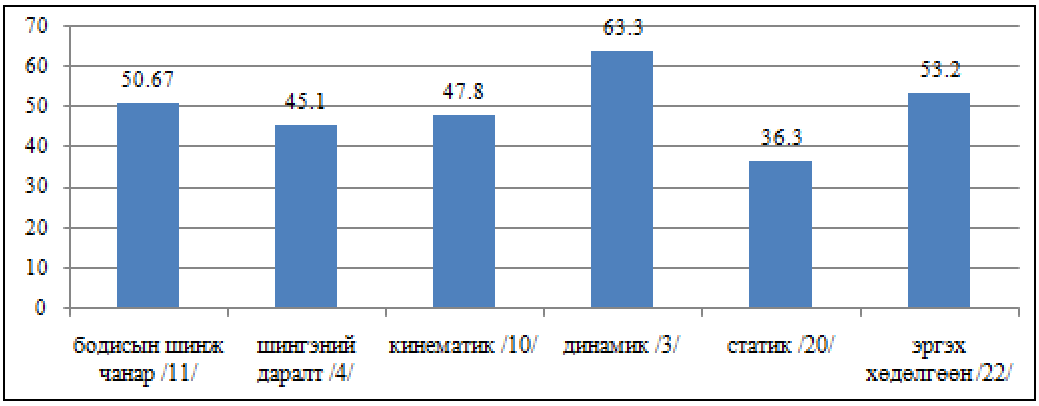


Chart 10: Bennett test performance (group of subjects)

Studying the Bennett method,the 70 problems of performance as a physics lesson content "dynamic" group problem performance is the highest (63.3%)(?), "static" group problem performance is the lowest (36.3%)(Chart 13). Average performance of 47.18% and average score of the students, 32.98 indicates the same thing, because if we say 33 questions were solved correctly out of 70, its performance rate is 47.14%.

For us, actions evaluating technical thinking in students with the Bennett test and its performance rate is very important. Especially because we aimed at locating the highest and lowest performed questions and analyzing skills indicated by those questions.

Table 5: Technical thinking level (by gender)

Gender	Percentage of students				
	Very low	Low	Medium	High	Very high
Male	15.77	27.11	22.83	21.92	11.23
Female	4.84	8.03	20.2	33.75	33.18

Looking at the above table, male students at "very low" level of technical thinking are of 5.8%, female students are 4.8%, male students at the "low" level is 27.1%, females 8%, "average" level male students is 22.8%, female students at 20.2%, "high" level male studentsat 21.9%, female students at33.8%, "very high" level male students 11.2%, female students at 33.2% (Table 5).

To get a clearer result of the Bennett method done on Mongolian students, we studied similar questions given on the General Entrance Examination. When studying how the Bennett test is related to the contents of the General Entrance Examination, these questions had the following similarities and differences:
1) Expressed by pictures
2) similar action skills are being evaluated
3) Questions in General Entrance Examination assesscognitive and thinking skills
4) Bennett test assesses "defining linking causes" a skill of technical thinking.

There has been 1 question in the 2012and the 2013 General Entrance Examination and 2 in the 2015 examination which are similar to Question No. 40, 54 and 64 of the Bennett test. 23,393 students in 2012, 24,574 students in 2013 and 10,274 students in 2015 took the physics test at the General Entrance Examination

Table 6: Blueprint of General Entrance Examination questions

Year, question	Category	Content	Comprehensive ability	Cognitive level	Skills
2012, 11	Change and interaction of physics qualities	Easy mechanism	Creating	Using	Discovering principles of physics occurrence and transformation
2013, 10					
2015, 7					
2015, 8					

The General Entrance Examination of 2012-2015 was developed based on the content of the national physics program. These questions chosen for the General Entrance Examination is directed at assessing skills of "discovering principles of physics occurrence and transformation" which is at the "using" level of cognitive skills and as for comprehensive ability it is included in the "creating" category.

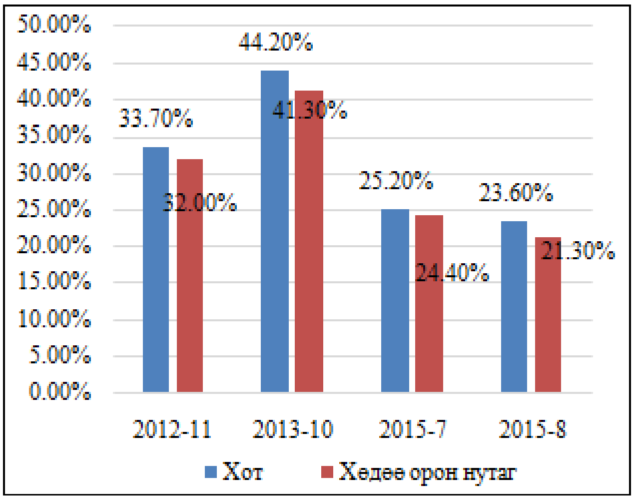


Chart 11: Performance at physics questions of General Entrance Examination.

Performance on question No. 11 in 2012 is 33.7% in the city, 32% in the rural area; performance on question No. 10 in 2013 is 44.2% in the city, 41.3% in the rural area; performance on question No. 7 in 2015 is 25.2% in the city, 24.4% in the rural area and performance on question No. 8 is 23.6% in the city, 21.3% in the rural area.

The data shows skills of "discovering the principles of physics occurrence and transformation" which is at the "using" level of cognitive skill and as for comprehensive ability it is included in the "creating" category , but is poorly developed. (Chart 6). This means that teachers don't use experimental tools and techniques often in thelaboratory and don't do experiments and don't work sufficiently to solve practical problems in the classroom.

Performance result of the Bennett test question No. 40, 54, 64

The content of the above 3 Bennett questions is similar to questions to assess skills of "discovering occurrence and transformation of physics" in Grade 12 physics program.

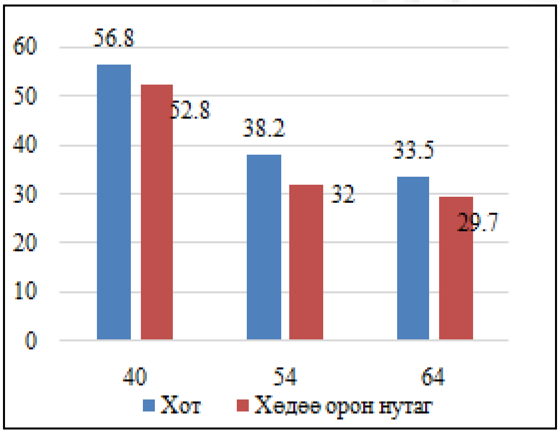


Chart 12: Performance of some questions of Bennett test

Performance on question No. 40 of Bennett test is 56.8% in the city, 52.8% in the rural area, performance on question No. 54 is 38.2% in the city, 32% in the rural area, and performance on question No. 64 is 33.5% in the city, 29.7% in the rural area.

An Overview of the results of the Bennett method used for evaluating technical thinking level of Mongolian students and research found on some problems of The General Entrance Examination,

- The content of some questions of the Bennett test is similar to the physics test blueprint of the General Entrance Examination. This means that in secondary schools, technical thinking skills are being developed at a certain level during physics lessons. Russia and other countries' researchers are assessing technical skills of their students using the Bennett test, therefore, it is suitable for Mongolian students as well. However, some of the questions of the Bennett test is too hard for our students, because certain technical thinking skills are not being developed through physics lessons.
- The median of the above questions' performance is 41.6%, theaverage performance of the General Entrance Examination questions is 32.9% in 2012, 42.6%, in 2013 23.8%, and in 2015 the median value being close, which means it is possible to assess technical thinking in students with the Bennett test, moreover, it is necessary to use the Bennett test examples for the General Entrance Examination.
- Laboratory observations tell us that students need to be provided with technical tools at laboratory and experimental classes, thus, improving experience of using technical tools, increasing their interest and making them voluntarily run experiments.
- It is important to give problems to solve, however, problems that need technical thinking, modeling, knowledge integration, creating knowledge, and error analysis skills need to be increased.
- Chart 13 shows that performance on "static" group problems that need technical thinking skills is very poor. This can be explained by the quality of the physics program, teachers' methods and the learning environment. Furthermore, anupdate on the concepts of physics education at secondary school levels and technological upgradesare much needed.

Results from observation on technical thinking in students

Sample.The current state of technical thinking developed by physics lessonsare assessed by observing laboratory lessons and problem solving classes.127 students from Ulaanbaatar advanced level schools and 129 students from regular schools, 256 students in total participated in the study.

Research method. Two observations were made

First, observation in laboratory class for "Defining personal resistance of transmitter",

Second, observation on process of solving a problem on "object movement that has been thrown at an angle".

Table 7: Technical thinking skills

Technical thinking skill	Skills that can be studied through observation	
	For laboratory classes	For problem solving
Fixing, updating **Modeling** Modifying Finding solution Defining connecting causes **Creating**	k_1 – experimenting skills, k_2- studying (studying theory and experimental methods) k_3-combining (combining information acquired through experiment) k_4 – concluding (concluding experiment results and knowledge) k_5- explaining (explaining results of occurrence and experiment) k_6- reaching solution (solving problem, reaching creative result)	k_1- studying (understanding the sentence) k_2- solving(using formula) k_3- combining(formula extraction) k_4 – concluding (problem result) k_5- explaining (problem result) k_6- reaching solution(making right calculation)

When assessing above skills, the criteria was developed by rubric method.

Table 8: Observation method to assess technical thinking in students

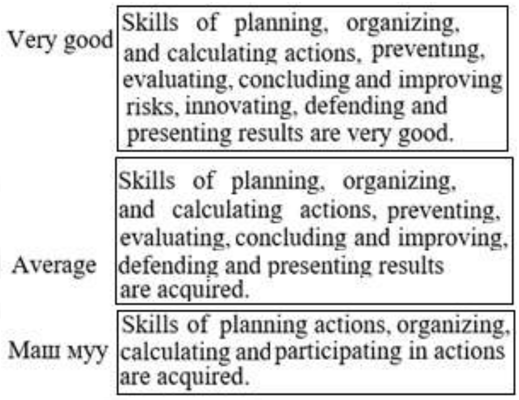
Evaluation	Average score	Score limit	Letter evaluation
Very good	22	24	A++
		23	A+
		22	A
		21	A-
		20	A--
Good	17	19	B++
		18	B+
		17	B
		16	B-
		15	B--
Average	12	14	C++
		13	C+
		12	C
		11	C-
		10	C--
Poor	7	9	D++
		8	D+
		7	D
		6	D-
		5	D--
Very poor	2	4	F++
		3	F+
		2	F
		1	F-
		0	F--

Method calculation,

1. To define normative level: $14 \div 4 = 3.5$
   3.5, approximately 4 and it's used for defining evaluation limit.
2. Maximum number should be 24.

$24 - 4 = 20, 20 - 4 = 16, 16 - 4 = 12, 12 - 4 = 5$

Evaluation of technical thinking skill assessed by observation is explained below.



Justification

1) When studying students' technical thinking, comparing score distribution evaluated by observation in laboratory and in solving problem with normal distribution, average performance of technical thinking is 14.14, standard incline is 3.529. Evaluation of the performance of students' technical thinking locates at the center of normal distribution, therefore, evaluation was practical and performance criteria was suitable. (Table 15).
2) When defining matrices' reliability of technical thinking skills evaluated by observance, the Coranbach's Alpha coefficient was 0.867, which is high, therefore, evaluation matrices used for the study is reliable and evaluation of technical thinking skill assessed by observation is practical. (Table 12).
3) The score limit of technical thinking evaluated by observation of students who belong to "good and very good" category of technical thinking level by Bennett method is 12-24.
4) There were 265 students who performed well in both the Bennett test and in observation which is 10.5% of total students.

4. Study Result

Table 9: Cronbach's Alpha coefficient

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.867	.864	12

Looking at the result of the questions given in physics class and skills which are being developed by them, the Cronbach's Alpha coefficient is 0.867, which is high, therefore, evaluation rubric and its criteria was suitable. (Table 12).

Technical thinking performances

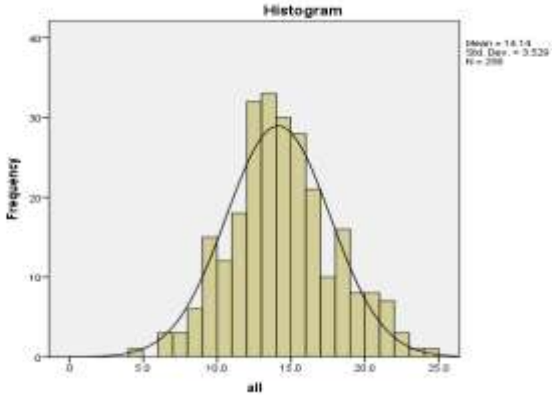


Chart 13: Evaluation of technical thinking skills (general)

How the technical thinking skills ofstudents were being developed by laboratory lessons and problem solving activity was evaluated by observation, and its average score is 14.14, standard incline is 3.529. Thisshows that the students' technical thinking skill evaluation score being located in the center of normal distribution, therefore, criteria was accurate and suitable. (Chart 16).

Every human action is influenced by internal and external factors. Therefore, this study has been expanded by factor analysis.

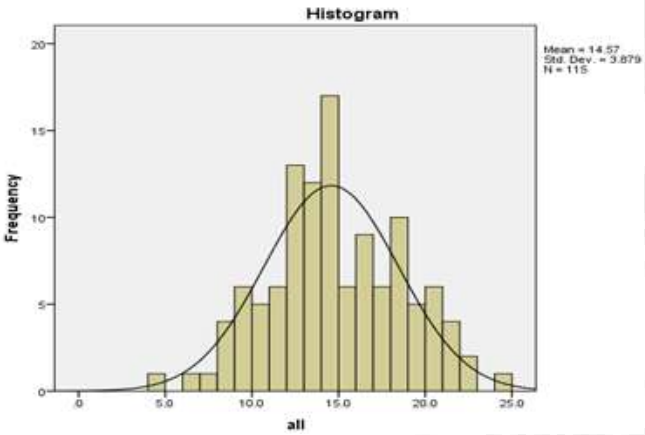


Chart 14: Students technical thinking skill evaluation (male)

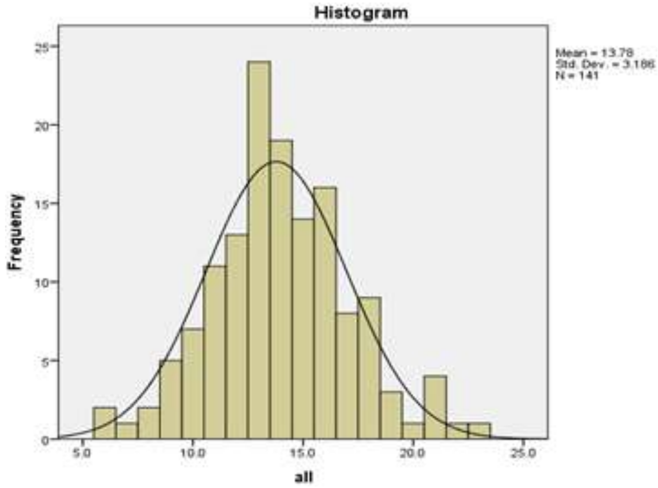


Chart 15: Students technical skill evaluation (female)

If we look at the gender factor of the technical thinking level, the average score of male students technical thinking is 14.57, the standard incline is 3.879, whereas the average score of female students is 13.78, the standard incline is 3.186 which means results of male students are higher than that of female students. (Chart 17, 18). Its external factor needs to be further studied.

Table 10: Students technical thinking skill evaluation (general)

	Number of students	Minimum value	Maximum value	Average	Standard mistake
Score	256	4.5	24.0	14.137	3.5293

The general performance of students' technical thinking evaluation shows that the maximum value is 24, the minimum value is .5, and the standard mistake is 3.5293 (Table 13).

Table 11: Students technical thinking evaluation (by gender)

Gender	Students		Technical thinking evaluation score				
	Number	Percentage	Average value	Median	Max value	Min value	Standard incline
Male	115	44.9%	14.6	14.5	24.0	4.5	3.9
Female	141	55.1%	13.8	13.5	23.0	6.0	3.2

The Technical thinking skill average score, the minimum and maximum values, and the standard incline are all different by gender. The minimum score of male students is 4.5, the female students' score is 6, the maximum score of male students is 24, the female students' score is 23 (Table 14).

As for students at advanced and regular schools, technical thinking skill evaluation assessed by observation in laboratory class and solving problem has gender differences as well.

Table 12: Students technical thinking skill evaluation (advanced and regular schools, by gender)

Class and gender		Number of students	Laboratory work				Problem solving			
			Average value	Max. value	Min. value	Standard incline	Average value	Max. value	Min. value	Standard incline
Advanced	Male	60	15	24	3	5	14	24	6	6
	Female	67	16	24	10	4	12	24	6	5
Regular	Male	55	18	24	6	4	11	24	6	5
	Female	74	18	24	6	4	10	24	6	4

a) Laboratory work

The average score of technical thinking skills in male students at advanced school is 15, female students is 16, male students at regular school is 18, female students is also 18. Looking at this, male and female students laboratory skills are almost the same, therefore, indicating that there is no difference in program content and teaching method at advanced classes (Table 15).

b) Problem solving

The average score of technical thinking skills in male students at advanced school is 14, female students is 12, male students at regular school is 11, female students is also 10, and the standard incline is 4.5 and 6, respectively. It shows that the problem solving skill level is much higher in advanced schools which could mean that at these schools, laboratory works are overseen and Olympiad prep is seen more important. (Chart 15).

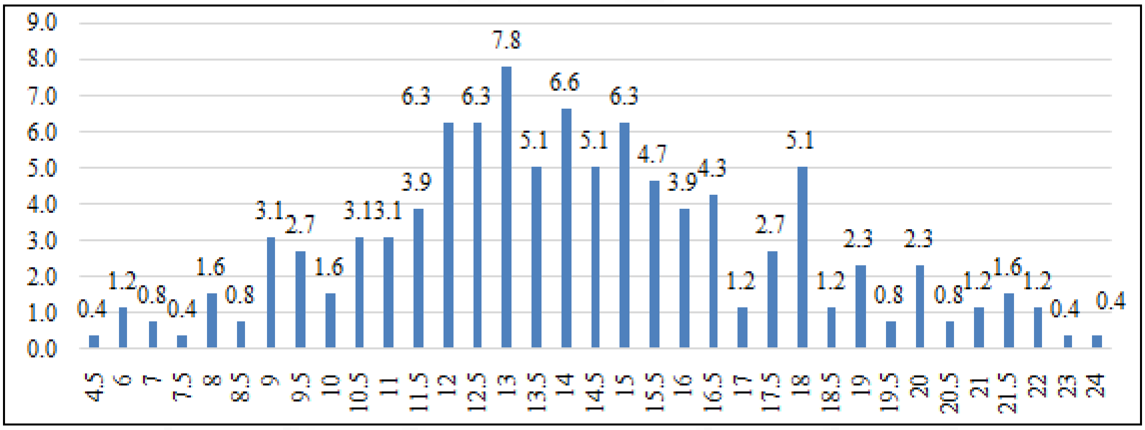
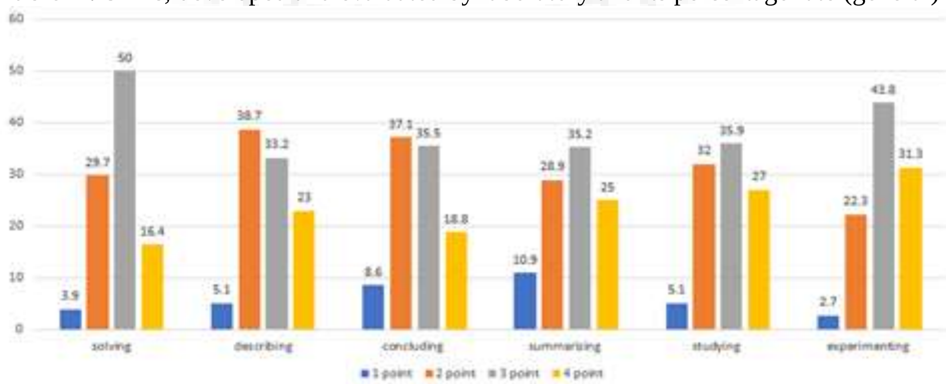


Chart 13: Students' technical thinking indicator

The detailed score distribution indicates that 0.4% of total students had the highest score of 24 and the lowest score of 4.5 (Chart 19). It could mean that laboratory work and problem solving teaching content is not directed toward developing technical thinking. You can see technical thinking skills, being developed by teaching at our secondary schools below.

Research *1, Laboratory work performance results.*

Table17: Skills, developed and evaluated by laboratory and its percentage rate (general)



We showed how some technical thinking skillsare being developed by laboratory lessons (Chart 20) which are as follows:

Experimental skill: 31.3% of total students had a score of 4, 43.8%had 3, 22.3% had 2 and 2.7% had a score of 1. This shows that the students' experimental skills and employing tools is developed at an average level.

Integration skill: 25% of total students had a score of 4, 35.2% had 3, 28.9% had 2 and 10.9% had a score of 1. This means that the students have low skills of integrating knowledge and experience from another study field.

Research skill: 27% of total students had a score of 4, 35.9% had 3, 32% had 2 and 5.1% had score of 1.This shows that students' skill of learning and understanding instructions, activity plan is low; moreover, the skills of acquiring knowledge from the content is poor.

Conclusion skill: 18.1% of total students had a score of 4, 35.5% had 3, 37.1% had 2 and 8.6% had a score of 1. It means that students have poor skills of concluding, arranging their activity, understanding its essense and purpose and using their knowledge.

Explaining: 23% of total students had a score of 4, 33.2% had 3, 38.7% had 2 and 5.1% had a score of 1.This indicates that we need to pay attention to students' skills of expressing their knowledge, making others understand and processing.

Reaching solution: 16.4% of total students had a score of 4, 50% had 3, 29.7% had 2 and 3.9% had a score of 1. It means that students need to learn how to pre-calculate activity outcomes, verifying the result and performing the duty in full. (Table 20).

To conclude, students have poor skills of learning and understanding activity instruction and plans, poor skills of acquiring knowledge, combining results, concluding, arranging their activity, understanding its essense and purpose and using their knowledge skills are low, moreover, skills of expressing their knowledge, making others understand and processing and pre-calculate activity outcomes, verifying the result and performing the duty in full needs to be Further developed

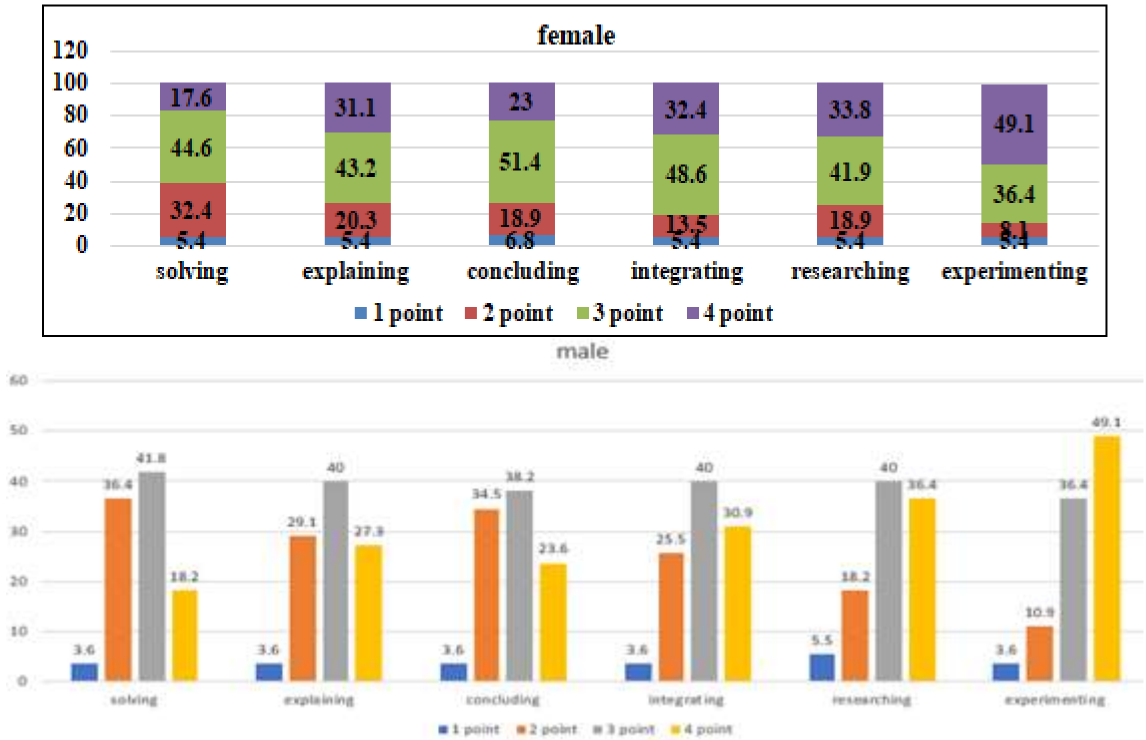


Chart 18: Skills developed and evaluated by laboratory (regular classes, by gender)

Looking at chart above, experimenting and researching skills are higher in male students than in female students, but skills of combining, concluding, explaining and reaching solution is higher in female students.(Chart 21)

The chart above shows that female students had a lower rate of low scores of 1 and 2 than male students, and had higher rate of high scores of 3 and 4 than male students which is an interesting indicator.

3.9% of male students, 5.6% of female student had a score of 1, 25.8% of male students, 18.7% of female students had a score of 2, 39.4% of male student,47.7% of female student had a score of 3, 30.9% male students, 27.9% of female students had a score of 4. It can be interpreted into that fact that the physics laboratory content and teaching method at regular schools and general teaching principles are directed at "average" students.

The chart above shows that skills of experimenting, combining, researching, concluding, explaining and reaching solutions are developed higher in male students than in female students in advanced schools. (Chart 22).

9.2% of male students, 5.5% of female student had a score of 1, 38.8% of male students, 44% of female students had a score of 2, 33.9% of male student, 33.3% of female student had a score of 3, 18.9% male students, 17.2% of female students had a score of 4.

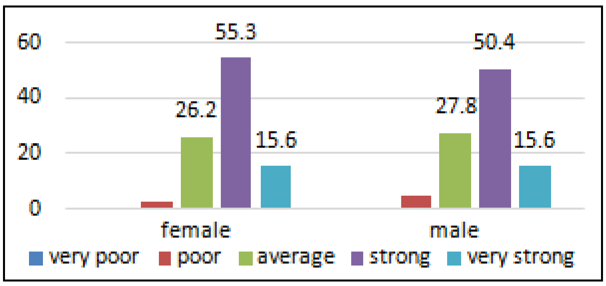


Chart 20: Technical thinking level developed by laboratory method (general)

The current practice of developing technical thinking skills in Mongolian students is at an average level. For example, the percentage rate of female students is "very bad, bad and average" category is 29.1%, among male students the average is 33.9%, which means 1/3 of students has no skills to solve creative problems. (Chart 23). At another look, factor skills such as explaining and concluding is developed at an average level. Relatively higher levels of using technical tools could be linked to the problem level solved by students and tools used for that purpose. Observations show that in recent years, secondary schools have modern tools and equipments, however, the teachers' use of them is not enough.

Research 2 and result of developing technical thinking skill with solving problems

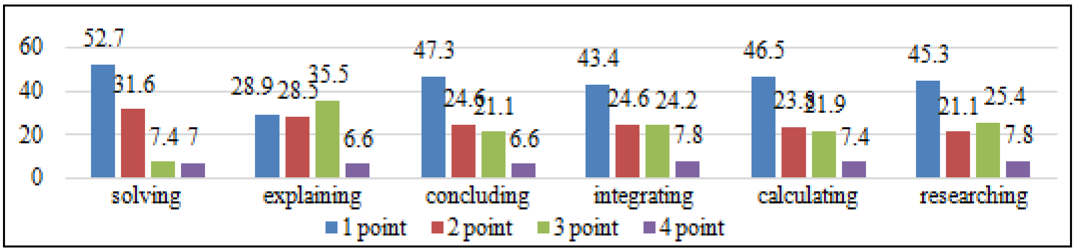


Chart 21: Students technical thinking evaluation (problem solving)

Looking at the result of how technical thinking skills have been developed through solving physics problems are as follows:

Solving skill: 7.8% of total students had a score of 4, 25.4% had 3, 21.1% had 2 and 45.3% had a score of 1, respectively. This shows that students have poor skill of problem solving.

Integration skill: 7.8% of total students had score of 4, 21.9% had 3, 24.6% had 2 and 43.4% had a score of 1, respectively. The result shows us that students have poor skills of combining and converting problem results.

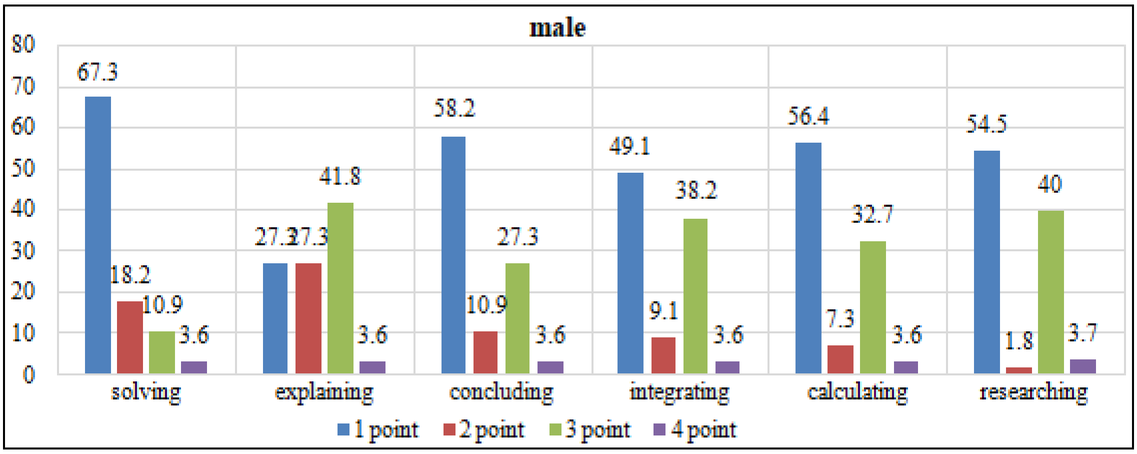
Researching skill: 7.8% of total students had a score of 4, 25.4% had 3, 21.1% had 2 and 45.3% had a score of 1. Looking at the result, it tells us students have poor skills of reading carefully and answering questions, as well as, acquiring knowledge of the given content.

Making conclusion: 7% of total students had a score of 4, 21.1% had 3, 26.4% had 2 and 47.3% had a score of 1 which indicates that explaining the solving method, proving with usage examples, understanding their goal and using their knowledge is at a very low stage.

Explaining: 6.6% of total students had a score of 4, 35.5% had 3, 24.6% had 2 and 47.3% had a score of 1, respectively. The result indicates that students need to pay more attention to develop their skills of using their knowledge in different situations, expressing and processing their ideas.

Reaching solution: 7% of total students had a score of 4, 7.4% had 3, 31.6% had 2 and 52.7% had a score of 1, respectively This also shows us that students need to learn skills of problem solving, doing mathematical solutions, proving the results and performing perfectly. (Chart 24).

All of the above could be concluded that overall, students have low skills of problem solving, combining and converting problem results, explaining their solution method, proving with practical usage, understanding the goal, using their knowledge, employing, expressing and processing their knowledge in different environments, problem solving, doing mathematical solutions, proving the result and performing perfectly.



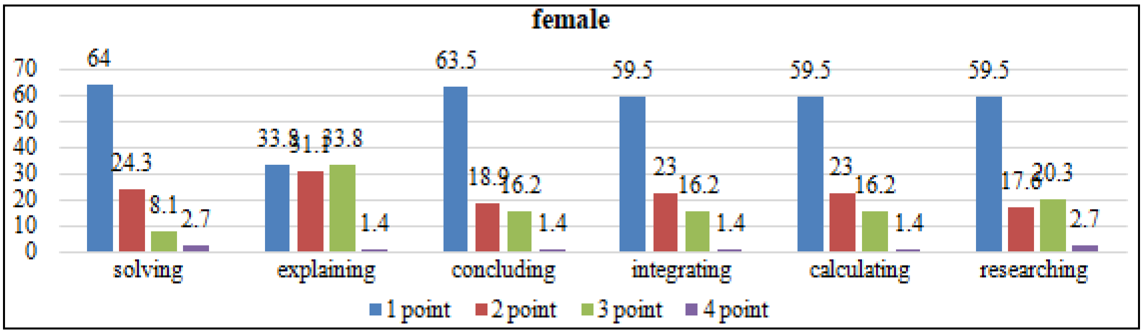


Chart 22: Technical thinking skill developed through problem solving (regular school, by gender)

The above chart shows inadequate results for both male and female students. (Chart 25). It shows that except for the explaining skill, every other skill has lower than 50% performance.

Female students at regular school who had a low score of 1 and 2 is much more than male counterparts.

52.1% of male students, 56.8% of female students had a score of 1, 12.4% of male students, 23% of female students had a score of 2, 31.8% of male students, 18.5% of female students had a score of 3, 3.6% male students, 1.8% of female students had a score of 4.

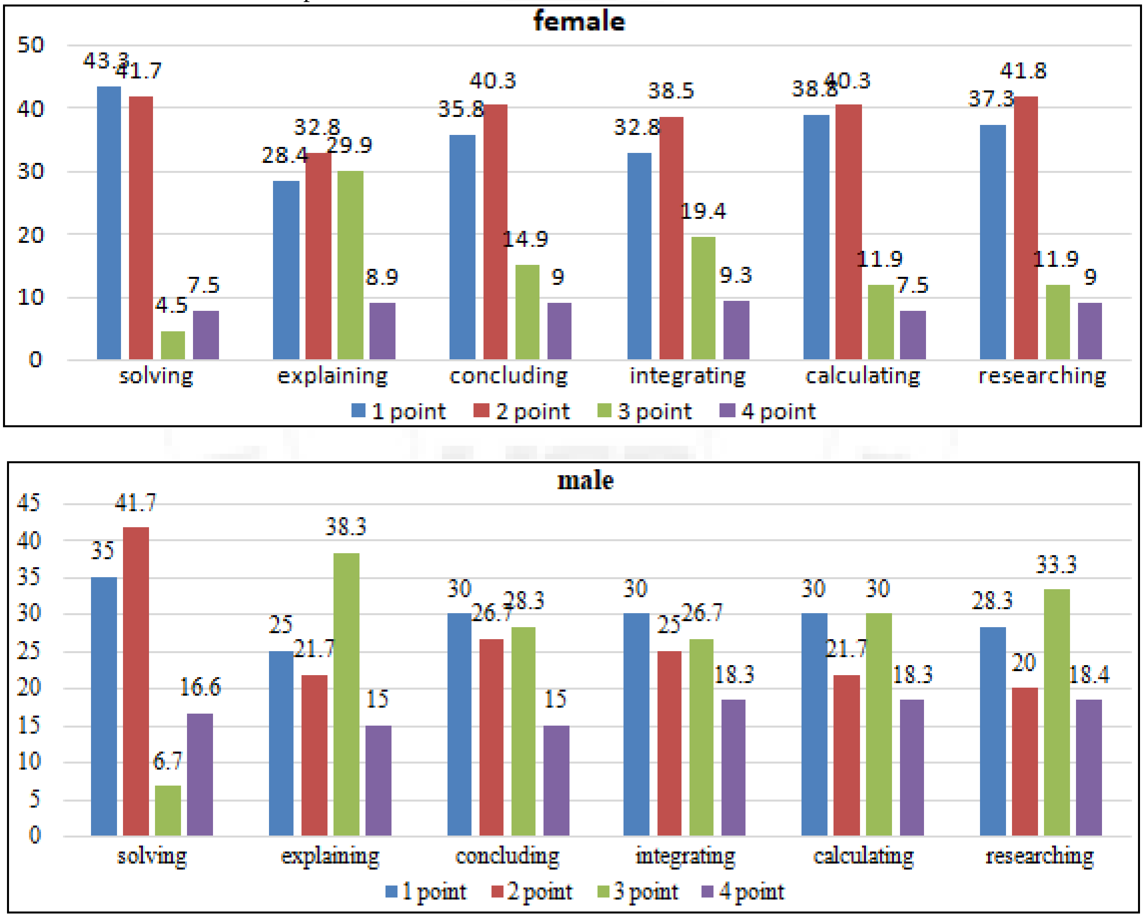


Chart 23: Technical thinking skill developed through problem solving (advanced school, by gender)

The technical thinking skills developed through problem solving (regular school, by gender) chart shows that the skills of male students are higher than that of female students. (Chart 24). Out of these skills, the "explaining" skill has the biggest difference in male and female students. As for above the skills of students at regular school, female students who got the lowest score of 1 and 2 are more than their counterparts.

29.7% of male students, 36.6% of female student had a score of 1, 26.1% of male students, 39.3% of female students had a score of 2, 27.2% of male students, 15.4% of female students had a score of 3, 16.7% male students, 8% of female students had a score of 4.

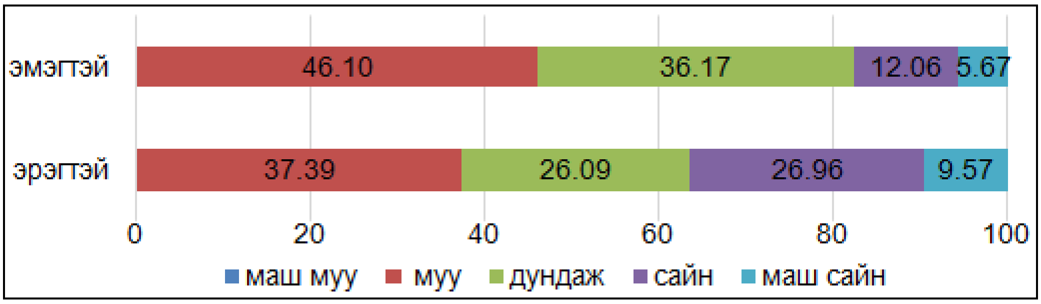


Chart 24: Technical thinking skill developed through problem solving (general)

The current practice of developing technical skills in Mongolian students is at an average level. For example, the percentage rate of female students among "very poor, poor and average" group is 82.3%, among male students it is 63.5% which means that 3\4 of total students don't have skills for solving creative problems. (Chart 27). More so, explaining, conclusion, integration, solution and combining skills are also poorly developed. It is important that natural science class should be a mandatory course so that it can develop technical thinking in secondary school students.

We are concluding the current practice of developing technical thinking in Mongolian students through solving physics problems in the following way. Students' performance on solving physics problems is at a lower than average level. For example, students who have not acquired skills of reaching solution are 83.4 percent, skills of solution; using algorithm is 80.3 percent of total students. This means that physics problems developed cognitive action rather than technical thinking skill. In other words, school programs do not use problems and questions that involve practical problem solving,finding new solution and method and modeling.

Study of factors developing technical thinking in students

Besides assessing students technical thinking level with the Bennett method, we also got surveys from all students in physics teaching methods and environments. As a result of these surveys, we studied if there were any correlation between technical thinking levels, assessed by the Bennett method and content result and wrote a regressionequation.

The correlation study was made between

a) Students technical thinking evaluation assessed by the Bennett method and factor
b) Students technical thinking evaluation assessed by the observation method and factor (Table 17)

Table 14: Influence of factors

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	606.504	5	121.301	11.801	.000[b]
	Residual	2569.711	3390	10.279		
	Total	3176.215	3395			
a. Dependent Variable: all						
b. Predictors: (Constant), bq13, bq7, bq12, bq9, bq10						

In the scope of study objective, there are 5 factors affecting the study of relations between technical thinking evaluation assessed by the Bennett method and its factors which are as follows:

- Integration between subject and content
- Using everyday materials for teaching
- Contents of textbook
- Percentage rate of students with good technical thinking in that class
- Laboratory class
- Durvin-Watson analysis value is 1.926, close to 2, therefore, it is proved "true" that there is no time or other influence on the students' technical thinking level assessed by observation. (Chart 19).

Chart 15: Regress analysis (action).

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.437[a]	.191	.175	3.2061
a. Predictors: (Constant), bq13, bq7, bq12, bq9, bq10				

When studying factor regression analysis with the development state of technical thinking by observation, it show that it has a medium level of influence from regressive coefficient indicator (R=0.496), (R^2=0.246) (Chart 19).

Chart 16: Betta coefficient value

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	13.432	1.094		12.278	.000
	Using integration between subject and content	3.909	.568	.530	6.878	.000
	Using everyday materials for teaching	.929	.448	.186	2.072	.039
	Quality of textbook content	2.837	1.051	.368	2.700	.007
	Percentage rate of student with good technical thinking in the class	2.331	1.034	.325	2.255	.025
	Laboratory class schedule	2.484	.602	.439	4.122	.000
a. Dependent Variable: all						

The study result shows that all Regressive Betta coefficient has positive values. (Table 20).
Equation of factor developing technical thinking through physics program (Table 20):

$$TCT= 0.53y_1+0.186y_2+0.368y_3+0.325y_4+0.439y_5$$

They are: TCT-technical thinking level
y_1- integration between subject and content
y_2- using everyday materials for teaching
y_3- content of textbook
y_4- percentage rate of student with good technical thinking in that class
y_5- laboratory class schedule

- It is proven that when the physics teacher increases skills of continuously using integration between subject and content in their teaching method by 10 percent, students' technical thinking level increases by 5.3 percent,
- When physics teacher increases skill of showing experiment, using everyday materials in their teaching method by 10 percent, students' technical thinking level increases by 1.86 percent,
- When content and quality of textbooks is improved by 10 percent, students' technical thinking level increases by 3.68 percent,
- When the learning quality of the class increased by 10 percent, students' technical thinking level increases by 3.25 percent,
- When the laboratory class is increased by 10 percent, students' technical thinking level increases by4.39 percent. And all these coefficients are important which is proved by statistics. P(Sig)=)0.00<0.05.s

5. Summary and Discussion

We conclude that our objectives of the study have been fully met which are explained as follows:

- Technical thinking is a habit of activity. Technical thinking is defined by defining, updating, modeling, modifying, combining or integration, finding new solutions, reasoning and creating skills in cause connection systems. Technical thinking is interrelated with students' cognitive, particularly, creative and critical characters.
- The Bennett method is proven to be suitable to assess technical thinking level of Mongolian students. Contents of some of the Bennett test questions were similar to the General Entrance Examination physics test blueprint, which means that there is no "cultural" influence and it is based on mechanical physics basic skills.
- Study results show that in secondary schools, technical thinking skill is developed at some level through physics programs. However, for our students, some of the Bennett test questions are hard, which means that certain technical thinking skills are developed at a poor level or not being developed at all.
- The technical thinking of Mongolian secondary school students was assessed at an "average" level. The Bennett test was suitable for students in Ulaanbaatar, however was more difficult for students in the rural area. It can be due to environmental difference where information is being received.
- Very poor performance on "static" group questions that require technical thinking skills could be linked to quality of the physics program, teaching method and environment.
- There has been no difference in advanced school physics program which means that there are no difference in teaching content, method and environment, so it is necessary to train teachers with technical thinking skills, using practical forms of teaching, bringing up to policy level to create an environment suitable for practical teaching and implementing.
- The result from the regression equation of factors developing technical thinking through physics shows that integrations between subjects, increasing practical content such as running experiment, using everyday tools and equipment and improving teachers' teaching method and technical thinking skill are necessary steps for technological education.

Limited result of the study is due to the fact that Bennett test and content survey has been conducted online and observation was made on only one laboratory work and one content scope.

6. Study Conclusion

The following conclusions have been made based on study results:
One. The following conclusion is made based on study on students' technical thinking level and technical thinking skills:

- The Bennett test questions are familiar and understandable to Grade 12 students of secondary school, and its contents, data and picture and average performance has normal distribution. It shows that Bennett method is suitable for the study.
- However, the General Entrance Examination has only a few questions that have similar data.
- The technical thinking of Mongolian secondary school students was evaluated as "average" level.
- The City students' technical thinking level was higher than students in rural area and it can be explained with an environmental difference.
- The City male students' score is higher than male students in rural area, but female students had no difference.
- The technical thinking of students at regular and advanced schools has similar level, so it means that there are small or no difference in learning environment, subject content and teaching method. Students at advanced school has a higher level of problem solving, but lower levels of laboratory skills, which could be explained by the fact that students spend more time preparing for olympiadsand less time using laboratory equipment and experiments.
- The laboratory lessons need to improve quality in a creative and scientific way and need to be able to develop technical thinking skills to explain the outcomes, using integration with scientific foundation and many other factors, regulating and prove with facts and expressing their ideas to others.
- There is a need to improve selection problemsused in physics programs by considering its quality, result and usability and developing technical thinking skills in

students such as uniting solution results, making conclusions, explaining, making conclusions of its everyday use, reaching solutions, etc.

- The General entrance examination of some years has similar questions with the Bennett test, so there should be no external factor affecting the performance on the Bennett test. In other words, content and data of the problem can be understandable.
- It is important to improve quality of laboratory and demo lessons which are an important feature of physics lessons and for a teacher to be able think creatively and use everyday materials for experiments. The more "creative" the teacher, the better technical thinking skills the student has. Based on this result, it can be concluded that teacher's technical thinking skill needs to be good and the teacher needs to plan and organize lessons in a more creative and efficient way.
- It is necessary to improve laboratory lessons in a creative and scientific way and for it to be able to develop students' technical thinking skills to explain the result using integration with scientific base, overviewing and verifying with facts, expressing and depicting it in a clear understandable way.
- There is a need to improve selection problems used in physics programsby considering its quality, result and usability and developing technical thinking skills in students such as uniting solution results, making conclusions, explaining, making conclusions of its everyday use, reaching solutions etc.

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