Research Article

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The Impact of Peer Collaboration in Enhancing Mathematics Teachers' Pedagogical Content Knowledge and Skills: Lessons from Tanzania

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Abstract: *It is reported that the Tanzania government is facing a big challenge of organising in-service education programmes that would have impact on mathematics teachers' pedagogical content knowledge and skills (PCK&S), which ultimately improve students' performance in the subject. By using development research approach, a study was designed to evaluate the impact of peer collaboration with the use exemplary materials in probability. The investigation involved 6 ordinary level (junior secondary) mathematics teachers and 130 Form 4 (12th Graders) mathematics students. In data collection, the study used triangulation process that involved observation of collaborative activities, interviews, and student test. Findings from this study revealed that teachers had adopted the collaborative activities that were promoted through the programme for the purpose of enhancing their PCK&S. Moreover, they were also stimulated to conduct other collaborative activities. Findings from students' test results showed that there was a significant difference between pre-test and post-test scores, demonstrating that students gained knowledge as a result of activity-based probability lessons. Combining the results from teachers' experiences with peer collaboration and students' learning, it can be concluded that the COllaboration to Support MAthematics Teachers (COSMAT) programme had yielded a positive impact on teachers' PCK&S and teacher collaboration.*

Key Words: Development research, peer collaboration, exemplary materials, school-based seminars and activity-based teaching

1. Introduction

Due to the fact that mathematics is very important in all walks of life, the Tanzanian government has been emphasising the need for regular in-service education to improve, among others, mathematics teachers' quality and professionalism. The government is committed to ensuring the provision of quality mathematics education. However, of major concern are the consistently low achievement levels in the subject, especially Basic Mathematics, among students at secondary school level.

Many reasons have been advanced to explain this state of students' poor achievement in mathematics. One of the major reasons that is frequently mentioned in the recent years is the quality of mathematics teachers. Due to the current expansion of student enrolment and the increase of secondary schools, there has been a shortage of qualified teachers. As a result, many schools have employed unqualified teachers such as ex-Form Six Leavers (students who have just completed their advanced level education only) to teach. They have also employed people with background unrelated to teaching and have failed to secure employment opportunities relevant to their courses. There are cases in schools where teachers teach mathematics even though it is not their subject of specialisation. Also schools employ under-qualified teachers such as Grade A's, who qualify to teach at primary school level. Moreover, those who are qualified to teach at this level of education, have significant problems due to poor preparations they received in colleges (Chonjo, Osaki, Possi & Mrutu, 1996; Jarvis, 1990). The majority of these teachers lack substantial subject matter knowledge, that is, knowledge of what to teach (content Knowledge), and how to teach the subject matter effectively (pedagogical knowledge) (Chonjo, *et al*., 1996 & Sichizya, 1997). Subject matter knowledge and pedagogical knowledge blend to form what is referred to as pedagogical content knowledge (Shulman, 1986). Pedagogical content knowledge (PCK) is the knowledge of how to transform formal subject matter knowledge into something appropriate for a particular group of students.

Because of the problems of pedagogical content knowledge teachers have, as well as classroom conditions, there was an urgent need for comprehensive teacher support programmes so as to improve the quality of mathematics teaching. This was especially necessary in view of students' poor performance.

The government recognises the need for teacher support for mathematics teachers in various ways. Through the then Tanzanian Ministry of Education and Culture (MOEC), local institutions such as the University of Dar es Salaam (UDSM); the Tanzania Institute of Education (TIE) and the Mathematics Association of Tanzania (MAT) organise teacher support programmes enabling teachers to receive high quality mathematics education. Other efforts have established collaborative donor-funded projects to receive support in these improvement efforts. One of the donor-funded projects is the Teacher Education Assistance in Mathematics and Science (TEAMS) project, which was based at UDSM. The TEAMS project focused on science and mathematics teacher education for both pre-service and in-service programmes, on staff development and development of teaching and learning materials (O-saki, 2007).

With regards to organising in-service education and training, the TEAMS project was facing a number of challenges. Because of the country's size, it was difficult to organise in-service education programmes that reach all mathematics teachers scattered in different schools throughout the country. One-shot in-service programmes might be possible, but it was difficult to organise follow-up sessions. Besides, current professional development literature indicates that one-short in-service education programme is not effective (Fullan, 2001) while the importance of follow-up in school level is widely recognised (Fullan, 2001; Showers & Joyce, 1996; van den Berg & Thijs, 2002). The TEAMS project was, therefore, exploring ways to provide teachers with school level support within the existing constraints. Peer collaboration, the practice of teachers supporting each other, was seen as a promising approach in this respect (Kwakman, 2003; Thijs, 1999).

Subsequently, a study into peer collaboration within the framework of the TEAMS project was started, which was known as peer Collaboration to Support Mathematics Teachers (COSMAT). In its development the COSMAT programme had four major components, including (Kitta, 2004):

- School-based seminar as the central focus of the study;
- Exemplary materials developed by a team and introduced in school-based seminars
- Facilitators as part of the materials development team, who coordinated and stimulated peer collaboration in schools;
- Peer Collaboration, a form of teacher professional development introduced via school-based seminars and stimulated use of exemplary curriculum materials in probability lessons.

2. Towards collaboration in mathematics teachers' professional development

Research on teacher professional development programmes gained momentum in the 1970s. Much of this research was based upon the work of Joyce, for example, Joyce & Peck (1977); Joyce & Showers (1995); Showers & Joyce (1996).

Literature shows that the continuing growth and professional development of teachers may be substantially enhanced by opportunities to collaborate with others (Fullan, 2001; Joyce & Showers, 1995; Nias, 1998; Showers & Joyce, 1996). The opportunity to take advantage of the expertise of others, and be recognised for their own, can provide teachers with important reinforcement and incentives for continuing growth and development.

Teachers who work closely together on matters of curriculum and instruction find themselves better equipped for classroom work (Inger, 1993). Another perceived benefit of collegial practice in schools has been introduced by Fullan (2001), who maintains that educational change is more successful when teachers work collaboratively. The acceptance of new ideas is encouraged through what he terms 'the primacy of personal contact' amongst teachers. Taking the argument further, the educational outcome of students can also be improved by the successful adoption of this new teaching practice.

Despite the fact that collaboration has often been hailed as the solution to individualism and the isolation of teachers, it has some limitations. One of the limitations of teacher collaboration is an organisational setting that does not allow teachers the time to collaborate (Pugach & Johnson, 1995; Thijs, 1999). This is because teachers are often confronted by pressure of work; they are responsible for heavy workloads and have limited time (Kwakman, 2003; Stuart, 1997) within the limited time in their schedules.

Also, collaboration is criticised for suppressing some of the important qualities of teachers as human beings associated with individualism. Fullan and Hargreaves (1992) caution that collegiality can suppress individuality and subject teachers to 'group-think', depriving them of independent thinking. Caution must be taken not to suppress all teacher individualism. Some of the aspects of teacher individualism such as caring, individuality, creativity and solitude are important for teacher effectiveness and confidence.

Apart from limitations, there are some challenges facing teacher collaboration. To be able to support each other to enhance their PCK&S, and in turn help students to learn better, teachers should have a sufficient knowledge base (http://education.stateuniversity.com/pages/2484/-Teacher-Prepartion).The majority of teachers in schools are not fully prepared in this respect, though (Ball & Cohen, 1999; Fullan, 2001). This, of course, makes realising the benefits of collaboration difficult.

Another challenge for implementing collaboration in schools is building collaborative cultures among teachers. Pugach and Johnson (1995) contend that collaborative interactions are not always easy as it involves a change of behaviour. Nevertheless, Fullan (2001) argues that there is no single answer for this and suggest that changes require some impetus to get started. He proposes to begin with small groups of people, and if successful, build momentum.

3. Purpose

The purpose of the COSMAT study was to explore, design and evaluate peer collaboration-a school-based teacher professional development model that aimed to provide ongoing support for mathematics teachers since literature indicates that peer collaboration has beneficial effects on teachers' professional development and continued growth (Fullan, 2001; Joyce & Showers, 1995; Showers & Joyce, 1996; Nias, 1998; van den Berg & Thijs, 2002). Peer collaboration means teachers working jointly to share their expertise and experience for the purpose of improving teaching, learning, and in this case, basic mathematics at the ordinary level secondary school. Very little was known in Tanzania about the potential of peer collaboration in relation to teacher professional development. The COSMAT study endeavoured to investigate the impact of this approach for mathematics teachers. More specifically, the study explored how peer collaboration could enhance their pedagogical content knowledge and skills.

4. Method

The COSMAT study followed a development research approach. Development research allows flexibility, step-by-step development of the programme, and is sensitive to the context. This is very important because peer collaboration was a relatively new paradigm in teacher professional development and, very little was known about how it worked within the Tanzanian context.

The COSMAT study was based on van den Akker's (1999) developmental research characteristics and was divided into three stages-the foundation building stage, the development stage and the evaluation stage. In the foundation building stage, the study's focus was to articulate tentative design guidelines for a potentially valid, practical and effective teacher professional development programme. Peer collaboration was considered the main component to enhance the mathematics teachers' pedagogical content knowledge and skills (PCK&S). Validity, practicality and effectiveness are quality criteria for a sound professional development programme (Nieveen, 1997; van den Akker, 1999). That is, the components of the programme should be based on state-of-the-art knowledge (content validity) and consistently linked to each other (construct validity). In terms of practicality, the COSMAT programme should be considered feasible by the target group and experts. Also it should be able to meet the needs of the teachers involved, the demands of the context in which they are working, as well as be consistent with the intentions of the developer. To be effective, the COSMAT programme should meet the expectations as expressed by the target group, improving mathematics teachers' PCK&S. To generate professional development guidelines appropriate to a Tanzanian context, preliminary investigation was conducted. The investigation included (a) a literature review on teacher knowledge, basics for teacher professional development, and support for teacher professional development, (b) an analysis of the context in which the COSMAT programme was to be implemented, (c) an analysis of the available data about other peer collaboration programmes to see how they worked, (d) and a consultation of experts for their appraisal of the programme. The preliminary investigation resulted in the initial components of the COSMAT programme.

The second stage of the study centred on the development and formative evaluation of COSMAT programme. According to van den Akker (2002), formative evaluation allows for judgements to be made on the strengths and weaknesses of an intervention in its development stages.

The third stage of the study focused on determining the programme's impact. Information was collected to determine how teachers perceived the COSMAT programme and how they put programme ideas into practice. The impact study served as a summative evaluation, which enabled the researcher to make overall judgements about the COSMAT programme's usefulness.

Sample and Participants

To determine the impact of the COSMAT programme 6 mathematics teachers from three co-educational schools: two private and one public were used for in-depth study on their ability to put programme ideas in practice. These teachers were selected because at the time of the study they were teaching Form 4 (12th Grade), where the topic of probability is taught. The criteria used to select these three schools were what Patton (1990) refers to as information rich. Since the study's intention was to gain more insight into the implementation of school-based peer collaboration in enhancing mathematics teachers PCK&S, the information rich schools were considered to be those with the following attributes:

- leadership that supports teacher professional development efforts;
- teachers willing to participate in the study;
- a form of teacher professional development efforts present that involved some type of peer collaboration;
- mathematics departments that have a considerable number of teachers;
- easy access to schools for the researchers.

Apart from teachers, 130 Form 4 mathematics students from the three schools were also involved in the study. All 130 students did pre-test before and post-test after the teaching of probability. Of 130 students, 30 were involved in the guided group discussion.

5. Instruments

In order to determine the impact of the COSMAT programme, several data collection instruments and procedures were used. These included interviews, tests and observation of peer collaboration activities.

Interviews

In this study, there were two sets of interview schemes: one for teachers and the other for facilitators. The teachers' interview scheme consisted of questions aimed at collecting in-depth information about the programme's contribution in enhancing their PCK&S in teaching of probability. It also contained questions about their opinions about peer collaboration and facilitator's contributions in fostering peer collaboration activities in their departments.

Test

Since the aim of the COSMAT programme was to improve classroom teaching, students' learning was explored. In order to collect information from students, one of the instruments used was a test. The test, which is shown in Appendix 1, consisted of 25 multiple-choice questions worth four points each. The test was developed by the researcher and covered all lessons in the exemplary material. The test was moderated by two experts: one from the University of Dar es Salaam and the other from the University of Twente so as to check its validity. The experts were guided by a table of specifications, which helped them relate to the objectives and content of the lessons. The Cronbach's alpha was computed to determine the reliability of the test. The higher the score, the more reliable the generated scale was. Nunnaly (1978) has indicated 0.7 to be an acceptable reliability coefficient. The overall alpha was found to be 0.79, which was good enough for this research purpose considering .70 is the cut-off value for being acceptable. The test was administered via pre- and post-test designs. The pre-test was administered before the teaching of probability. After the teaching, the same test was administered to the same group of students to see whether the probability lessons taught through an activity-based approach had an impact on their learning.

Collaborative activities

In order to facilitate data collection of peer collaboration activities that took place in the mathematics department at each study school, facilitators were asked to take notes on these activities. This would help them accumulate information about activities that would take place informally, without prior notice to the researcher. The researcher and the research assistant also participated in taking notes on activities that were taking place in schools. All those involved were informed of the type of information they were to collect during these activities. Information collected was compiled ready for report writing.

6. Findings and discussion

The impact of the COSMAT programme was determined with respect to the evaluation levels as inspired by Guskey (2000). Specifically the evaluation focused on participants' reactions, their reflection on the design specifications of the curriculum materials in connection with the actual use of the programme ideas in classrooms, teachers' perception and students' experiences and learning outcomes.

Overall, the teachers' reactions to the programme were positive. Through the seminar with the exemplary materials, teachers felt that their confidence and competence in teaching had been improved in terms of both subject matter knowledge and teaching skills, especially on probability topic. Through the seminar, teachers indicated also to have gained a clear picture about how peer collaboration could be conducted, which motivated them to organise collaborative activities. These findings are consistent with the study by Mafumiko (2006) who also in a similar context found that exemplary materials with procedural specifications on critical aspects of the curriculum enables teachers to work with and learn about new approaches without an extensive initial orientation. However, these findings are based on teachers' self-reports, taken alone do not give direct evidence about the impact of the programme in the real user setting (school classrooms). On the other hand, including such information is useful, because if participating teachers do not value the content and approach of the programme, it is very unlikely that they would expend the effort to implement programme ideas and recommendations.

School visits and interviews with teachers also showed that teachers had adopted the collaborative activities that were promoted through the programme for the purpose of enhancing their PCK &S.

In terms of student performance and experiences with the COSMAT programme, findings from students' test results showed that there was a significant difference between pre-test and post-test scores, demonstrating that students gained knowledge as a result of activity-based probability lessons. This is a promising result, because probability is a topic that teachers indicated to be amongst the most difficult curriculum mathematics content area. The findings also indicate that students valued the topic of probability as being useful in day-to-day activities. They seemed to appreciate the activity-based teaching approach (most of the time involving group work) as useful, practical and interesting. They also perceived the team-teaching approach as useful since it helped them gain knowledge from the shared expertise of two teachers.

Combining the results of the three data sources (teachers' perceptions, observations in classroom and schools, and student learning experiences), it can be concluded that the COSMAT-programme has yielded a positive impact on teachers' PCK&S and teacher collaboration. In the next section this impact findings are presented and discussed in more detail.

(1) Teachers' perceptions of peer collaboration

The study also sought to explore the impact of the collaborative activities as perceived by teachers. Table 1 gives the summary of the areas in which teachers thought the collaborative activities had impact on them.

Through interviews, all six teachers from the three schools acknowledged that they benefited from collaborative activities both in subject matter knowledge

Table 1 Perceived impacts of suggested peer collaboration activities

Activity	School A	School B	School C
Co-planning of lessons	—Enhanced competence using activity-based teaching	—Enhanced competence using activity-based teaching	—Discovering weaknesses in lesson planning
Study groups (Including discussion on past exam papers and solving students problems/questions)	—Consolidated subject matter knowledge —Filling knowledge gaps	—Consolidated subject matter knowledge	—Clearing doubts about some areas in the topic —Consolidated subject matter knowledge
Team teaching	—Promoting collegiality —Enhanced competence using activity-based teaching		—Promoting collegiality Enhanced competence —using activity-based teaching

Table 2 Problems encountered in conducting collaborative activities

School A	School B	School C
— Lack of time	— Lack of time	— Lack of time
— Clashing timetable	— Double sessions	— Double sessions
— Teachers leaving the school	— Clashing timetables	—Preparation and marking of mock exams
— Occupied by private tuition		— Occupied by private tuition

and activity-based teaching approaches as shown in Table 1.

Teachers from all three schools claimed that collaborative activities consolidated their subject matter knowledge. While teachers from School A argued that the collaborative activities helped them fill knowledge gaps that they had in the topic, their colleagues from School C argued that the activities helped them discover the weaknesses in the planning of lessons and cleared some doubts they had pertaining to some areas in the topic. Regarding activity-based teaching, teachers from School A and School B contended that collaborative activities, especially team teaching and co-planning of lessons helped enhance their competence in using the approach.

Constraints in conducting peer collaboration activities

When interviewed, all six teachers identified several constraints (See Table 2) they faced in conducting collaborative activities in their respective schools.

Table2 shows that lack of time was indicated as one of the major problems all three schools faced in conducting collaborative activities. They associated the lack of time with congested timetables and the marking of large numbers of student exercise books. Teachers from School B and School C noted that the existence of double sessions in schools was another problem whereby mathematics teachers are split into two groups in such a way that it made it difficult for them to get the opportunity to conduct peer collaboration activities. Teachers from School A and School B considered clashing timetables as another constraint in conducting collaborative activities. This was specifically associated with team teaching. Team partners were sometimes allocated to teach at the same time in different classes. Teachers in School A and School B claimed that their meagre salaries forced them to use any extra time they were getting to conduct private tuition or do other small projects so as to make ends meet.

In summary, teachers from the three schools conducted a number of collaborative activities that included co-planning of the lessons, team teaching, study groups and joint preparation of students' tests. Though teachers appreciated the importance of peer collaboration, time was a major constraint for them to benefit from the scenario. The time constraint was associated with clashing timetables, double sessions and teachers being involved in private tuition.

(2) Students' experiences and learning outcomes

The study also explored students' experiences and learning outcomes with the activity-based probability lessons. These experiences, which were collected through guided group discussions and by a paper-and-pencil probability test, were classified into two parts: students' perceptions and students' learning from the programme. Students as ultimate beneficiaries of change or innovation, the information gathered from them was considered useful for gaining insight into the potential impact of the programme on teachers.

Students' general opinions about probability lessons

Table 3 Pre-test and post-test results for all the three schools

Test	Mean	SD	N	t
Pre-test	32.6	12.9	130	29.6*
Post-test	63.8	17.4	130	

Note: *is statistically significant ($p<0.05$)

Table 4 Pre-test and post-test scores for individual schools

Test	School A				School B				School C			
	Mean	SD	n	t*	Mean	SD	N	t*	Mean	SD	n	t*
Pre	40.3	14.7	50	17.84	28.6	8.7	45	18.49	26.9	8.5	35	14.94
Post	71.9	20.4	50		58.3	13.6	45		59.2	12.3	35	

Note: *is statistically significant ($p<0.05$)

In general, all the students (n=30) from the three schools who were involved in the guided group discussion were positive about the probability lessons. They said that the topic in general was interesting because it was taught through activities and experiments instead of just listening to the teachers and writing notes.

Students' perceptions of team teaching

Since the teaching of probability involved team teaching, students were asked to give their opinions about the presence of two teachers in their classroom during the teaching of probability lessons. Students had mixed opinions about this issue. However, the majority of them supported the idea and few of them did not like it. Those who liked the idea asserted that when two teachers were in the classroom, they helped one another make the lessons more understandable to students. Because the practice was not common in schools, one student claimed that

> *At the beginning, when I saw two teachers in the classroom, I was surprised, but when the teachers started teaching and support each other, I liked so much.*

Those who supported the practice also contended that team teaching was good because it helped promote attention and seriousness on the part of students. They further argued that each teacher had his/her style of teaching that helped make it easier to understand the probability lessons.

The few students (n=5) who did not like the idea of having two teachers in the classroom said that the situation not only gave teachers very little freedom and autonomy, but also interrupt students' attention. One student argued that:

> *It was not fair to have two teachers in the classroom because it interfered students' attention; they were feeling shy in answering questions as well as asking questions about the areas they did not understand. The idea makes some teachers not to teach properly because of the presence of his/her colleague in the classroom.*

Student learning

Students did the same test before and after the teaching of the probability lessons. Table 3 shows the overall performance for all the three schools pooled together.

Table 3 shows that for all the three schools there was a significant difference between pre-test and post-test indicating that learning took place as a result of teachers using exemplary materials. Table 4 shows the performance of individual schools.

From Table 4 it can be gathered that in overall performance, School A scored higher in both pre-test and post-test than School B and School C. The difference might be due to the teachers' performance in the classroom.

(3) Some lessons from the COSMAT study and reflection on Japanese lesson study

(a) Peer collaboration introduced via school-based seminars with the aid of exemplary curriculum materials is a relatively new approach to teacher professional development in Tanzania. When designing and planning peer collaboration through school-based seminars or workshops there is a need to reflect on adult learning theory considering that teachers are life-long learners but they are adult learners. Transformative learning which involves transforming 'habits of mind and/or 'point of view' are the most significant type of learning for adults (Mezrow, 2000 cited in Ono, 2008). How teachers perceive and learn with peer collaboration their existing beliefs and knowledge need to be thoroughly examined if their PCK &S are to be enhanced through peer collaboration and school-based seminars.

(b) The role of curriculum (exemplary) materials as a positive model is only possible in the context of professional development that challenges the existing beliefs and knowledge that teachers bring to these materials. The 'inert' characters of curriculum materials need to be recognized because they do not by themselves generate positive changes in classroom practices. They are a tool that teachers can use to enact innovations. The behaviour and beliefs of the teacher are a critical factor in how the innovation /new programmes are implemented (Powell and Anderson, 2002).

(c) The appreciation of teachers on the collaborative activities, such as co-planning of lessons and student tests, team teaching, and study groups as revealed in the COSMAT study supports the collaborative nature of any professional development work. In this regard Reitzung (2002) argues that even though there may be some opportunities for isolated work and reflection, most effective professional development happens when there are meaningful interactions, not only among teachers, but also with administrators, parents, academicians and community members.

(d) An example of good practice of an effective professional development, which is highly interactive (involves many stakeholders) and is good to learn from it, is the Japanese's lesson study. Lesson study is a professional development process which teachers progressively strive to improve their teaching skills by working with other teachers to examine and critique one another's teaching technique. It is a means of enabling teachers to develop and study their own teaching practices (Isoda, Stephens, Ohara, & Miyakawa, 2008). The process involves "Plan, Do, See" collaboratively planning the lesson, observing its implementation in the class, discussing, revising the lesson, re-teaching revised lessons (optional) and sharing reflections about the process (Fernandez and Yoshida, 2004). These elements of lesson study could provide useful ideas to improve the COSMAT programme, especially on development of exemplary materials and school-l based seminars.

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要　約

タンザニア政府の数学教員の教授学的知識と技術を向上させるための現職教員研修は大きな課題を抱えているとされている．今回確率分野を事例としてOレベル数学教員6名と12学年生徒130名を対象に，観察，聞き取り調査および学生に対するテストを行い，数学教員支援協働（COSMAT）プログラムの評価を行った．その結果，数学教員はプログラムを通じ，協働するようになり，教授学的知識と技術を向上させている．また活動中心の確率の授業を受講することで学生の成績も前後で向上している．従ってプログラムが正の影響を与えていることがわかった．

（教員教育国際協力センター）

Appendix A

Probability Test for Form 4 Students

Time: 1:30 Hours

Instruction: ***Answer all the questions by circling the letter of the correct alternative for each item***

1. Probability is a branch of mathematics which is concerned with the
   (a) measure of certainties
   (b) measure of uncertainties
   (c) measure of mathematical ability
   (d) measure of mathematical capability
2. Which of the following is the probability experiment?
   (a) Tossing a coin (c) A head
   (b) A red ball (d) A blue colour
3. Which of the following is sample space when the two coins are tossed?
   (a) {H, T, H, T} (c) {HH, HT, TH, TT}
   (b) {H, T} (d) {TT, HH}
4. What is the probability of getting a head when a fair coin is tossed once?
   (a) 1 (c) $\frac{1}{2}$
   (b) $\frac{1}{4}$ (d) 0
5. If a fair die is tossed, what is the probability of getting a prime number?
   (a) $\frac{1}{6}$ (c) $\frac{2}{3}$
   (b) $\frac{1}{3}$ (d) $\frac{1}{2}$
6. Three coins are tossed simultaneously. What is the probability that three heads appear?
   (a) $\frac{1}{3}$ (c) $\frac{3}{8}$
   (b) $\frac{1}{8}$ (d) $\frac{2}{3}$
7. Which of the following experiments does NOT have equally likely outcomes?
   (a) choosing a number at random between 1-7
   (b) Tossing a fair coin
   (c) Choosing a letter from the word CARTOON.
   (d) Tossing a fair six-sided coin
8. All of the following are mutually exclusive events when a day of the week is chosen at random EXCEPT
   (a) Choosing a Monday or choosing a Tuesday
   (b) Choosing a Saturday or choosing a Sunday
   (c) Choosing a weekend or choosing a weekday
   (d) Choosing a Saturday or choosing a weekend
9. In probability, when two or more events are represented by a single event, they are called
   (a) mutually exclusive events (c) dependent events
   (b) independent events (d) combined events

10. A student is chosen at random from the class of 26 girls and 24 boys. What is the probability that the student chosen at random is not a girl?

(a) $\frac{13}{25}$ (c) $\frac{12}{25}$

(b) $\frac{24}{25}$ (d) $\frac{1}{25}$

11. A teacher chooses a student at random from a class of 30 girls. What is the probability that the student chosen is a boy?

(a) 1 (c) $\frac{1}{30}$

(b) 0 (d) $\frac{1}{15}$

12. If spinner with 4 equal sectors coloured yellow, blue, green and red is spinned and a coin is tossed. What is the probability of landing on yellow and a tail?

(a) $\frac{1}{2}$ (c) $\frac{1}{6}$

(b) $\frac{1}{4}$ (d) $\frac{1}{8}$

13. A die and a coin are tossed simultaneously. Find the probability that an even number greater that 3 and a tail appear.

(a) $\frac{1}{2}$ (c) $\frac{1}{6}$

(b) $\frac{2}{3}$ (d) $\frac{1}{3}$

14. Mary has 3 blouses: red, blue and yellow. She has also 2 skirts: white and green. What is the probability that she will put on a blue blouse and a green skirt?

(a) $\frac{1}{2}$ (c) $\frac{1}{3}$

(b) $\frac{1}{6}$ (d) $\frac{1}{4}$

15. A single letter is chosen at random from the word TEACHER. Find the probability of choosing an E or a T?

(a) $\frac{3}{7}$ (c) $\frac{3}{4}$

(b) $\frac{2}{7}$ (d) $\frac{1}{7}$

16. In probability, we say that two events are independent if

(a) the occurrence of one event is related to the probability of the occurrence of the other.

(b) the occurrence of one event is not related to the probability of the occurrence of the other.

(c) one and only one event among the two events can take place at a time.

(d) two are represented by a single event.

17. A spinner has 5 equal sectors labelled A, B, C, D and E. What is the probability of landing on A or D after spinning a spinner?

(a) $\frac{1}{5}$ (c) $\frac{4}{5}$

(b) $\frac{2}{5}$ (d) 1

18. A single six-sided die is rolled. Find the probability of getting a number greater than 3 or an even number.

(a) $\frac{2}{3}$ (c) 1

(b) $\frac{5}{6}$ (d) $\frac{1}{2}$

19. All of the following are mutually exclusive events when a single 6-sided die is rolled EXCEPT
(a) Getting a number less that 4 or getting a number greater than 4.
(b) Getting a 2 or getting an odd number
(c) Getting a 2 or getting an even number
(d) Getting a 4 or getting a prime number

20. A coin is tossed and a single six-sided die is rolled. Find the probability of getting a head on the coin and a 5 in the die.

(a) $\frac{1}{6}$ (c) $\frac{1}{3}$

(b) $\frac{1}{2}$ (d) $\frac{1}{12}$

21. A box contains 5 red, 4 green, and 6 black balls. A ball is chosen at random from the box. After replacing it, a second ball is chosen. What is the probability of getting a green and a black ball?

(a) $\frac{10}{15}$ (c) $\frac{10}{75}$

(b) $\frac{8}{75}$ (d) $\frac{8}{15}$

22. In a shipment of 20 computers, 4 are defective. Three computers are randomly selected and tested. What is the probability that all three are defective if first and the second ones are not replaced after being tested?

(a) $\frac{1}{4}$ (c) $\frac{1}{720}$

(b) $\frac{1}{30}$ (d) $\frac{1}{180}$

23. If a fair coin is tossed once, what is the probability of getting a head and a tail?

(a) 0 (c) $\frac{1}{2}$

(b) 1 (d) $\frac{1}{4}$

24. On a math test, 6 out of 25 students got an A. If two students are chosen at random without replacement, what is the probability that both got an A on the test?

(a) $\frac{36}{625}$ (c) $\frac{6}{25}$

(b) $\frac{3}{50}$ (d) $\frac{1}{20}$

25. Mr. John needs two students to help him with a science demonstration for his class of 18 girls and 12 boys. He randomly chooses one student who comes to the front of the room. He then chooses a second student from those still seated. What is the probability that both students chosen are girls?

(a) $\frac{2}{3}$ (c) $\frac{3}{5}$

(b) $\frac{51}{145}$ (d) $\frac{36}{145}$