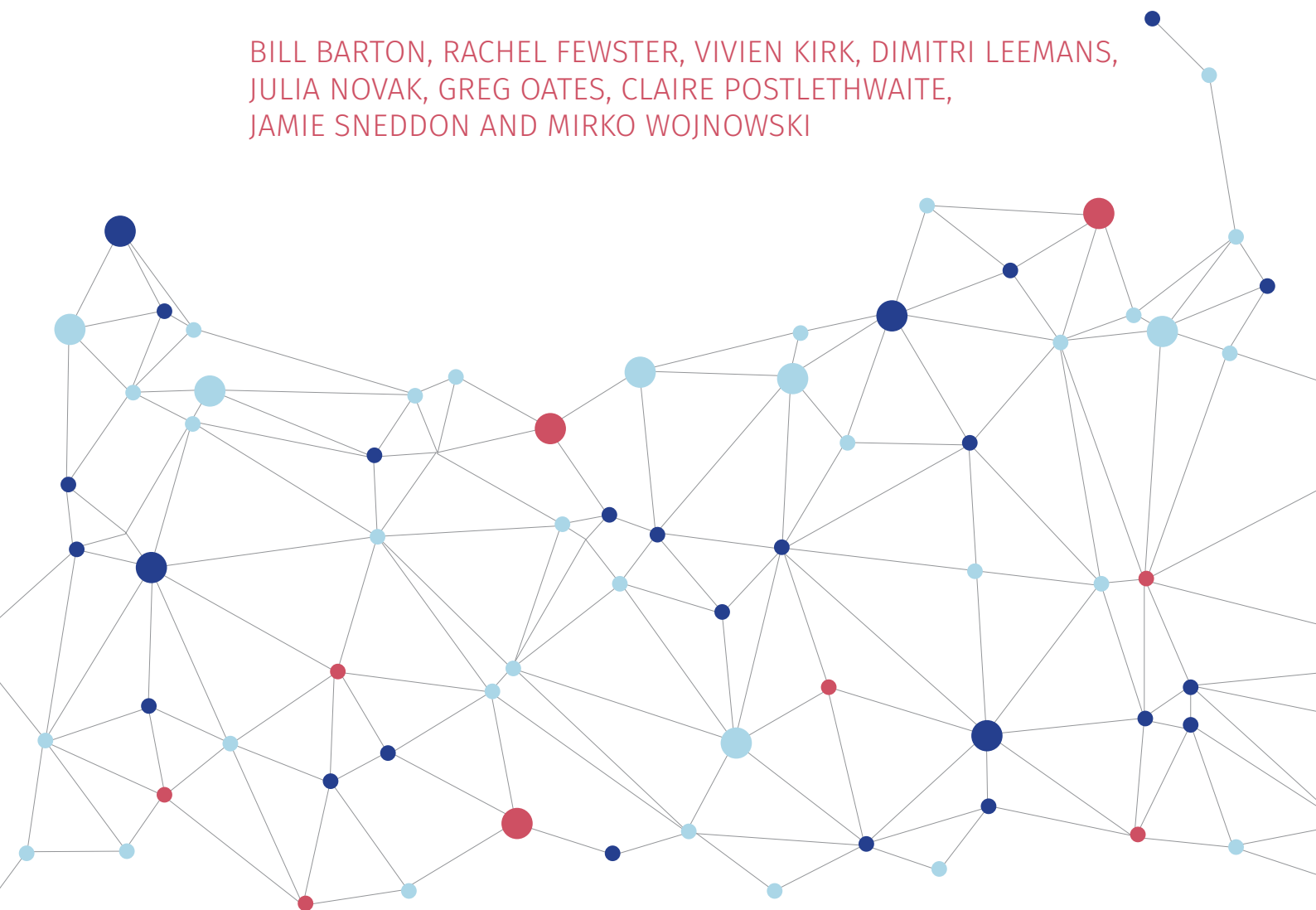

**LEARNING IN UNDERGRADUATE MATHEMATICS:
THE OUTCOME SPECTRUM (LUMOS)
"HOW TO" GUIDES**

Implement team-based learning

BILL BARTON, RACHEL FEWSTER, VIVIEN KIRK, DIMITRI LEEMANS,
JULIA NOVAK, GREG OATES, CLAIRE POSTLETHWAITE,
JAMIE SNEDDON AND MIRKO WOJNOWSKI



A series of "How to" guides

"HOW TO" GUIDE #1: This guide is one of seven produced by the project Learning in Undergraduate Mathematics: The Outcome Spectrum (LUMOS). LUMOS examined the learning outcomes of undergraduates in the mathematical sciences.

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"How to" Guide #1: Implement team-based learning

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"How to" Guide #5: Monitor the development of mathematical communication

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LEARNING IN UNDERGRADUATE MATHEMATICS: THE OUTCOME SPECTRUM (LUMOS).

"HOW TO" GUIDE #1: IMPLEMENT TEAM-BASED LEARNING

Authors

Bill Barton, Rachel Fewster, Vivien Kirk, Dimitri Leemans, Julia Novak
Greg Oates, Claire Postlethwaite, Jamie Sneddon, Mirko Wojnowski

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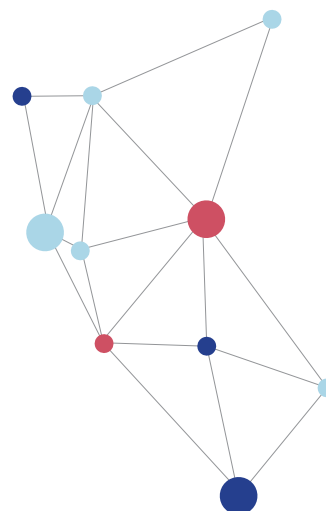
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Dedication

This Guide is an aspect of the LUMOS project which was managed by Judy Paterson. Sadly, Judy passed away during the course of the project. However, the legacy of her enthusiasm, energy, expertise in mathematics education, and dedication to improving undergraduate mathematics lives throughout the project, and particularly in the implementation of Team-Based Learning.

We dedicate this guide to her memory.

– Bill, Rachel, Vivien, Dimitri, Julia, Greg, Claire, Jamie, and Mirko

Team-based learning (TBL): What is it? Why use it?

Team-Based Learning (henceforth TBL) is a specific course delivery technique originally developed in the 1970s by Larry Michaelson at Oklahoma University. It was initially adopted in a medical training context, and then in a business environment (Michaelson, Knight, & Fink, 2002). Since then it has been adapted to many college courses, and has been the subject of considerable research (see Haidet, McCormack, & Kubitz, 2014). An on-line community dedicated to TBL exists (www.teambasedlearning.org), and many custom-made resources are available in New Zealand.

The essential features of TBL for undergraduate courses are:

- Preliminary reading or working.
- Individual and team assessments on the preliminary reading/work.
- Working in teams.

TBL techniques can be used throughout a course, or as a component of a course.

The benefits of using TBL techniques in undergraduate mathematics include:

- Increasing the quantity and quality of pre-lecture reading or work.
- Providing an opportunity for argumentation and other communicative skills.
- Scaffolding students who are struggling to understand a particular concept.
- Practising working mathematically in teams.

Used in conjunction with conventional lecturing and tutorials, TBL can offer a different learning experience for students and lecturers alike. Our experience with TBL from university foundation, undergraduate, and graduate courses is that students are generally positive about TBL, and use the opportunities it provides constructively. Lecturers who have tried it generally seek to repeat the experience.

In the LUMOS project, TBL was used at foundation, undergraduate, and graduate levels. All lecturers involved continue to view TBL as a favourable delivery model and continue to use it, in some form, in the trial course. Positive outcomes noted by lecturers included much needed training in team behaviour, and improved social dynamics in the class. TBL also seems to be a more satisfactory delivery mode when the course contains students from different backgrounds and levels of preparedness.

The general opinion is that, in an undergraduate degree, at least one TBL experience is a good idea. Also, TBL seemed to work better for some courses than others, but in our project, we did not come to any definitive reasons why this should be so.

We trialled TBL on both conventional mathematics and statistics courses, and also on a Mathematics Education course and a Tutoring in Mathematics course. It suited all types of courses.

Students were overwhelmingly positive about the experience in their evaluations of the course. They enjoyed being more involved in lectures, and talking with other students about the course content.



Overview of using TBL in undergraduate mathematics

Our recommendation is to use TBL techniques in conjunction with lectures and tutorials. Our recommendation is to use one TBL session every two weeks. We found that the normal amount of course content could be delivered using such a programme. Occasionally an extra TBL session can be inserted without compromising content coverage. TBL will not work in classes of less than 12 students because there are not enough groups to apply some of the standard TBL techniques.

The TBL structure used in undergraduate mathematics courses is as follows:

- Students are arranged in teams of 3-4 by the lecturer at the start of the course.
- The course is divided into a number of modules. Students are required to do a pre-reading before the first lecture of each module. At the beginning of the first lecture students are tested on their understanding of this reading using a short-answer test, and their answers collected.
- Then, in their teams, they answer the same test again, discussing each question in turn and scratching the appropriate answer on a scratch card. If they are wrong, they may then have another discussion and scratch a second answer, and so on. The marks achieved will depend on how many scratches are needed to find all the correct answers.
- Both the individual and team test marks are recorded and count towards the overall grade for the course. These tests are called RATs (Readiness Assessment Tests).
- The material in the module is then taught in the usual way. At some point, usually towards the end of the module, time is spent on a team task that requires the students to apply the ideas learnt in the module. The task may have individual and/or group assessments that contribute toward an overall grade.
- Tasks can be of many forms: standard problems from the course (of the complexity and difficulty of assignment problems, rather than examination problems); open-ended explorations of situations related to the course; creative tasks such as inventing new notations or representations; or technology-based tasks using mathematical environments or tools.

Setting the environment

As is normal for any new course characteristics, students need to be informed clearly about what is happening, how it will impact assessment, what is expected of them, and why it is being implemented.

Students will have mixed experiences with teamwork, particularly if it has involved assessments. In particular, some “good” students fear their grades will be depressed as a result. Our experience was that initial suspicion was replaced by positive feelings, especially from female students.

It is therefore important to make clear in advance the assessment structure of the course, and how individual and team marks are taken into account. A short class discussion on this may be useful. We recommend that team marks form a relatively small proportion of the overall grade, especially if it is the first experience of TBL for most students. (See the section on Assessments below for recommended proportions).

In preparation for TBL, the course material needs to be divided into a number of modules, each covering 2-3 weeks’ work. Many courses already have this structure. However, in one of the trials we found a section of the course that would not fit neatly into a module of sufficient size. In the end, this section was taught in a standard way after the TBL modules.

Ideally, a practice TBL session should be held, so that students become familiar with TBL techniques, especially the Readiness Assessment Tests (RATs). This practice session is a good opportunity to revise pre-requisite knowledge and skills. It can also be an opportunity to motivate students with a contemporary and catchy reading.

Students should be arranged in teams of 3-4 by the lecturer at the start of the course. Note that TBL literature recommends teams of 5-6, but our experience for mathematics classes is that this is too many, especially if computer laboratory work is involved. Teams may need to be adjusted near the beginning of the course if students change their programme.

It is good to mix the students (well-prepared with less well-prepared, ESOL students with native English speakers, etc). The aim is to distribute the attributes that are associated with success in the course fairly across the teams, for example, background mathematics skills, English proficiency, and student effort. As attributes can be hard to evaluate, a useful technique is to distribute a “bio” questionnaire in the first session to gather relevant data, and then select teams on that basis.

Details of the approach

Readings and Problems

A key part of TBL is the initial reading or task. Various types have been tried successfully in mathematics undergraduate classes, with advantages (+) and disadvantages (-):

	<i>Advantages +</i>	<i>Disadvantages -</i>
<i>A section from a textbook</i>	+ Easy to generate	- May not exactly cover topic
<i>A set of notes prepared by the lecturer</i>	+ Tailor-made	- Time-consuming to prepare
<i>A set of problems</i>	+ Can be generated from past courses	- Difficult to set so students can learn something
<i>An open-ended mathematical situation to explore</i>	+ Popular with students	- Difficult to set a test from
<i>A published article on the topic</i>	+ Ideal for setting a test	- Hard to find
<i>A section of a book written for a general audience</i>	+ Ideal for setting a test	- May not be sufficiently in-depth

The important feature of the pre-reading or pre-task is that a short multi-choice test can be generated from it (see over page →).

RATs and other beasts

Students are required to do a pre-reading or pre-task before the first lecture of each module. They are then assessed both individually and as a group on the reading or task with a short-answer test.

The individual Readiness Assessment Test (RAT) occurs first thing in the lecture, and should take no more than 10 minutes. The reading or their pre-task work may not be used in answering this test. Individual answers on a pre-printed sheet (see Appendix 1) are collected. Students should be reminded to keep a note of their answers for use in the next activity.

Students are then moved into their teams and attempt the test again, discussing each question in turn until they agree on the answer. The appropriate answer is scratched on a scratch card. If they are wrong, they have another discussion and scratch a second answer, and so on. If only one answer is scratched, and it is correct, they receive a mark of 3, if two they receive 2, if three they receive 1.

The scratch cards are sometimes referred to as IF-AT (Immediate Feedback Assessment Technique). Prepared cards are available online from the USA by ordering from www.epsteineducation.com/home/order.

Both the individual and group test mark are recorded and count toward the overall grade for the course.

The questions for the RATs must be short answer questions, with four possible answers. For a reading, where the questions are comprehension questions, the RAT should be ten questions long. In a mathematical context some questions may involve calculations, and hence take longer. A RAT of six questions will be sufficient in this case.

A useful part of the RAT procedure is the post-test discussion. Often the RAT process exposes different points of view, unresolved arguments within teams, or challenges to the “correct” answer. Such issues need to be dealt with immediately in a whole-class session.

The literature on TBL includes a variety of ways to organise Team Tasks—activities during which students work together. We recommend at least one such activity per module. We also recommend that it includes an assessment that counts towards the final grade. The assessment can be individual, team-based, or both.

One effective way of organising a Team Task is using the Jigsaw model. Each member of the team is given a number from 1-4 (or however many members are in the team). The activity is broken into sections, and all the #1 members from the different teams initially get together to work on the first part, the #2s work on the second, and so on. After a short period, the teams reform and then the #1 explains his/her section to the other members of the team, the #2s follow, and so on.

The advantages of this structure are that students get to work with other members of the class rather than just their own team, and that each student has to take on the role of “teacher” as well as “learner”. It is a particularly useful structure if the team task involves a longer reading that can easily be broken into parts, or a sequence of problems that relate to each other. For example, a problem that may be approachable numerically, analytically, and graphically.

Assessments

Typically, a TBL course is assessed with coursework and an examination. The examination is the same as usual. Coursework may include a mid-semester test and assignments as usual; however, to make room for TBL assessments we recommend using only one of these. Trying to include all types of assessment makes the allocated marks too small to be taken seriously.

The TBL assessments are the RATs (both individual and team marks) and any Team Task assessments. A possible allocation of marks is as follows:

Individual RATs:	
4 tests @ 2.5 marks each	10%
Team RATs:	
4 tests @ 2 marks each	8%
Team Tasks (Individual or Team)	
4 @ 3 marks	12%
Assignments or Mid-semester test:	20%
Examination:	50%
Total	100%

If a student is absent for a RAT or Team Task they do not get the credit. This has a very positive impact on attendance.

Issues to be aware of

Working environments

TBL requires that work in teams is prioritised. An important aspect of this is an environment where the seating and availability of, for example, whiteboards, is conducive to team work. Attempting to undertake TBL in a tiered lecture theatre will be less successful, and will not indicate a commitment to teamwork.

University architecture means that purpose designed team rooms will not always be available. However a lecturer can:

- Request a flat floor plan rather than a tiered one.
- Request a room with no podium.
- Request a room with whiteboards at the side as well as in front.
- Make sure that group-writing facilities are available—for example, if not whiteboards, then large sheets of paper and markers.
- Move students into better arrangements—for example, group work is impractical if more than two students are in a row (students are often resistant to moving, but after two or three sessions where they are moved, they will move themselves).

A team environment is not just physical. Good team functioning is the lecturer's responsibility. A good strategy is for the lecturer to promote the reasons for, and value of, teamwork. Even better, is for the lecturer to model good team behaviour: listening carefully to others, and actively seeking others' views, as well as offering their own views clearly and ensuring all members of the group understand.

Many students are unused to working in teams and will resist it for a variety of reasons. Thus, initially, the lecturer may need to be quite forceful about team involvement. This means being active during teamwork sessions and identifying students who are being left out of, or not engaging with, the group.

Several students who perceived themselves as above average may express concern that their assessment

scores may be negatively affected by being part of a group. While we did experience this phenomenon in the trial, after the first two or three assessments the students' concerns were allayed as they perceived that all RAT group marks were always equal to or better than the mark of the best student in the group. The team tasks were mostly of this nature.

Another technique is to ask students to evaluate each other's contributions to the team. This may, or may not, be included as an official assessment. Either way, it makes students take their team role more seriously.

If language problems exist, then it may be necessary to adjust a team so a student has access to someone who can help. If the problem is shyness, then a quiet word to a mature member of the team to be inclusive can help. Our experience is that, quite quickly, virtually all students will participate fully and feel positive about the experience.

Marking

While the multichoice RATs do not present a marking problem, the Team Task assessments need to be carefully designed for large classes, so that they do not become an onerous duty. One technique is to ensure the answer to a Team Task is a diagram or graph. This can be quickly marked. If the assessment is a team assessment, then strict limits need to be put on the size of the response, otherwise the responses tend to be too big. For example, some teams will work individually and then submit the collected individual contributions.

If the Team Task assessments replace assignments, then whatever resources were used in the past to mark assignments can now be used for the Team Task assessments.

Teaching demands

Much of a TBL course is taught in the usual way. Apart from the extra task, noted above, of ensuring teams are functioning properly, the other specific teaching skill is the post-RAT discussion, where listening carefully to alternative opinions and ideas is very important. Students may feel that their views have been ignored in their team's discussion, so the post-RAT discussion is a place where it can be acknowledged and valued as a contribution to discussion irrespective of its "correctness". We all know that, in mathematics, misconceptions or errors often lead to better understanding and deeper learning.

Lecturers wishing to adopt TBL practices are advised to observe some TBL sessions—not necessarily in a mathematical sciences subject. We found that having two lecturers, possibly both novices, for a first time TBL delivery was useful. Partly this is because the TBL

environment opens up opportunities for new styles of questions and activities, and having a bigger pool of potential ideas was very useful. There are new administrative practices to get used to, as well as an increased importance on communication with students if they are unfamiliar with TBL. Having some models of these to observe is important.



Appendix 1

Individual RAT Answer sheet

Name:

ID#:

Team:

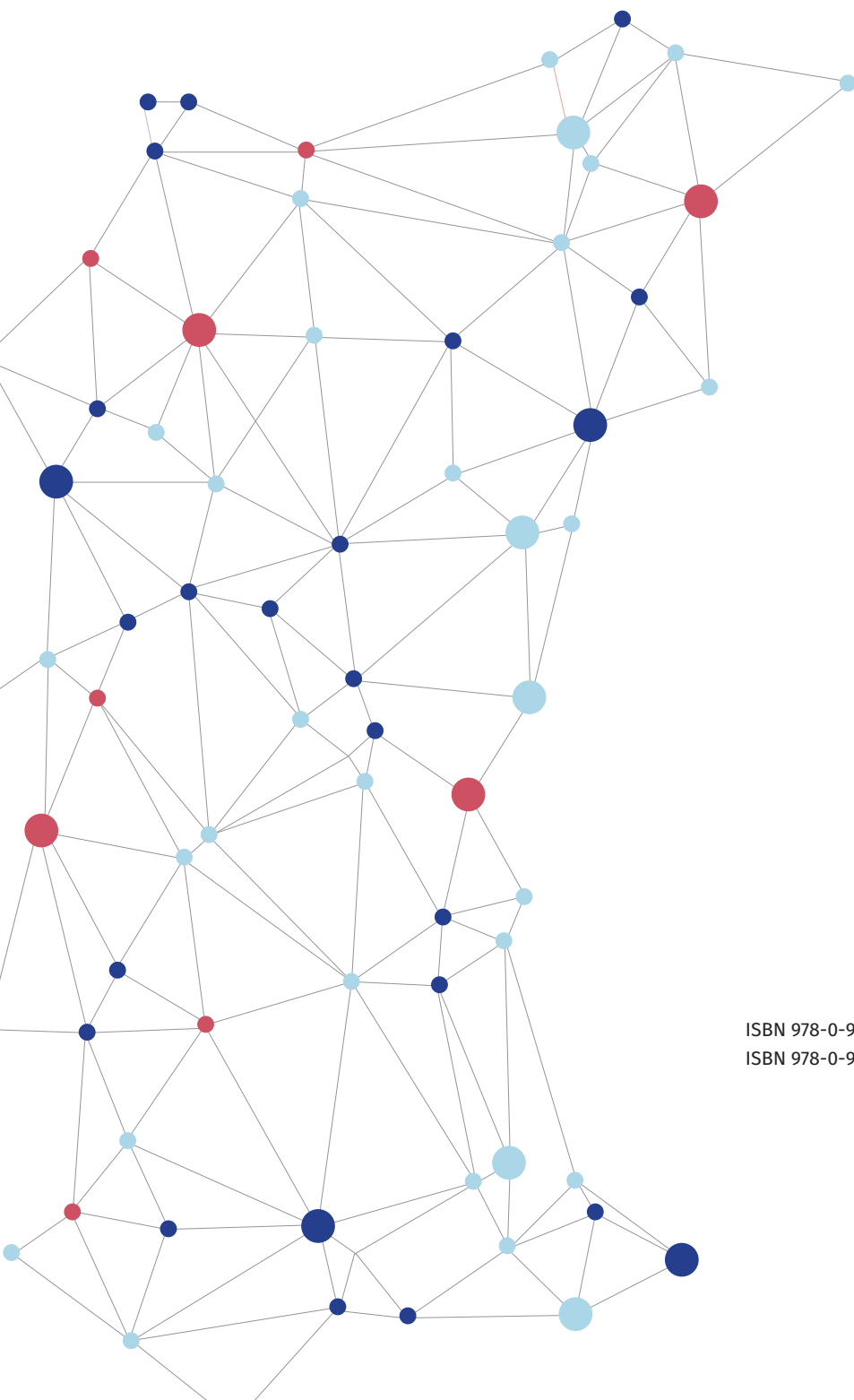
Question

1	a	b	c	d
2	a	b	c	d
3	a	b	c	d
4	a	b	c	d
5	a	b	c	d
6	a	b	c	d
7	a	b	c	d
8	a	b	c	d
9	a	b	c	d
10	a	b	c	d

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