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Lovisa Sumpter
Dalarna University

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Cover Page Footnote
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Recreational Mathematics—Only For Fun?

Lovisa Sumpter

Dalarna University, Falun, SWEDEN
lsm@du.se

Synopsis

In this paper, I explore recreational mathematics from two perspectives. I first study how the concept appears in educational policy documents such as standards, syllabi, and curricula from a selection of countries to see if and in what way recreational mathematics can play a part in school mathematics. I find that recreational mathematics can be a central part, as in the case of India, but also completely invisible, as in the standards from USA. In the second part of the report, I take an educational historical approach. I observe that throughout history, recreational mathematics has been an important tool for learning mathematics. Recreational mathematics is then both a way of bringing pleasure and a tool for learning mathematics. Can it also be a tool for social empowerment?

1. Introduction.

To do mathematics just for the pleasure of it is a popular activity; we find mathematical games such as sudoku and kakuro in newspapers and apps for our mobile phones. Doing mathematics for fun, otherwise called *recreational mathematics*, has a long history [30]. One of the oldest finds of written problems and their solutions is the Rhind papyrus from Egypt, dated 1650 B.C, that not only contains arithmetical tasks but also a few problems of recreational nature [30, 32]. These types of problems are simply and elegantly formulated. They resemble elusive riddles (enigmas), with the goal of catching the readers' interest and encouraging them to take them on as an intellectual challenge. We can also see in them a pedagogical value, in the same way that Socrates used problems in order to start a discussion. But the question remains: Why should you engage in such activities?

Looking at previous work on recreational mathematics from a historical perspective, I have not found extensive research on this question [3, 4]. Here I will try to approach it from an educational perspective using political and historical arguments. If we want to understand mathematics as a social phenomenon, we need to understand "the social forms in which mathematics manifest itself" [3, page 12]. Here the social form is mathematics education and the mathematical topic recreational mathematics. The research question I pose here is: "In what ways do modern policy documents reflect historical thinking about recreational mathematics?"

2. What is Recreational Mathematics?

To answer my research question, I have begun with a literature search. First we need to try to distinguish what is recreational mathematics and which components make it recreational. But these questions do not seem to have unique answers. Trigg [30] tried looking at different definitions, examples, and journals. He came to the conclusion that to define recreational mathematics "is not recreational" [30, page 18].

Most of the definitions presented in [30] have a reference to play, with positive affective components connected to it. This resonates with recent research in recreational mathematics. Jiménez and Muños [14] conclude in an endnote that a mathematical game is similar to recreational mathematics. Games and play both refer to the existence of a creative element, which can encompass several aspects such as person, process, and product [16], and the interplay between these aspects. The person has to want to solve the task with positive motivation, the solution process has to be viewed as joyful, and the product (the problem with its solution) at least somewhat interesting and possibly fun. These are all subjective; it is the individual herself who decides if her subjective experience is positive, if her motivation to do something is intrinsic, or if the problem sounds interesting.[1] As characteristics within intrinsic motivation, we can use subscales such as *challenge* and *enjoyment*, the latter one emphasising the relationship between motivation and emotions [1]. If the motivation to do something is enjoyment, positive emotions are in interplay with the motivation. Emotions, that here should primarily have

[1]You can see the relation between the reader and the topic in Madachy's description of the purpose of the section titled "Recreational Mathematics" in the journal *Fibonacci*: "This column, hopefully, will serve the need for mathematical relaxation" [18, page 60].

a positive orientation, can be defined as an affective reaction [10]. In this sense, emotions are more of a gut reaction than a cognitive process [11].

The second aspect to consider is the possible educational benefits of recreational mathematics. Topics can come from many different mathematical areas such as algebra (e.g. diophantine equations), graph theory (e.g. shortest graph) to geometry and probability [30]. But recreational mathematics can also include poems, rebuses, or puzzles such as sudoku. Again we are dealing with a subjectivity factor. You should do something that requires some cognitive effort, but what this cognitive effort might be is harder to define on a general level; it is determined by the relation between the individual and the problem.

The formulation of the problem seems to play a central part in recreational mathematics. David Singmaster, quoted in [9], claims that the story (that often is part of the problem) in it self is unlikely and that partly makes the problem memorable and pleasurable. This is also a subjective factor; what is memorable and what triggers motivation? However we will put this aside for the sake of simplification; even though it can be a part of a recreational problem, the formulation is not a defining factor and will not play a significant role in our work.

Then to summarize, at least for the purposes of this article, recreational mathematics is an activity where the person wants to solve the problem based on positive motivation (most likely intrinsic); the activity is linked with positive emotions, and it has some educational dimensions, although topics may range over different mathematical areas.

3. Why Recreational Mathematics 1.0?

Now we come to the central question of this paper. *Why engage in recreational mathematics?* In the first part of this report, I approach this question from a comparative educational policy perspective. In particular I review different educational policy documents such as standards, curricula, and syllabi from a selection of countries: China, England, Finland, India, Japan, Singapore, Sweden, and the United States.[2] The countries were chosen to

[2] Although not a national policy document in the same way as a curriculum or a syllabus, the Common Core Standards [5] are the closest to one that I could find for the United States at this time.

represent different locations, educational cultures and outcomes in previous international tests such as TIMSS and PISA. However, I certainly do not claim that this is a representative sample on a general level, since no countries from Australasia, Central America, South America, or Africa are included. Also, most documents, in all cases except for the texts from Sweden, Finland, and the English-speaking countries, are translated into English from their original language. I can in these cases therefore only rely on the translators.

A note on my methodology.

I located all texts on the Internet (see reference list for webpages). First I looked at where the purpose of the subject is stated (such as aim for school mathematics or core of the standards). Then, I went on to review the sections where the mathematical content is listed (e.g. standards) and other supplementary materials. I marked any reference to a notion that could be related to recreational mathematics, such as *pleasure*, *enjoyment*, or any other positive affective dimensions, then analysed by using the concepts *emotions* and *intrinsic motivation*, and finally summarised from the three perspectives: *person*, *product*, and *process*. Below, I present the results by country. Omitted passages not relevant to the study are indicated with [...].

3.1. China

Apart from understanding mathematical knowledge, in the Chinese curriculum (for age 6-14) [19] we can read that children should also display progress and development in the affective areas such as attitudes, emotions, and values. This strand is called *Affection and Attitudes* and students are supposed to "[p]ossess some degree of creative spirits and practical abilities, and develop sufficiently in areas of general abilities, affection and attitudes" [19, page 10]. Furthermore, they should be able "to participate positively in mathematical learning activities; demonstrate curiosity and eagerness in mathematics learning" [19, page 11]. The teachers, therefore, "should pay attention to both levels of children's mathematics learning and the emotions and attitudes exhibited during mathematical activities" [19, pages 5-6].

We can see how the desired development in affection and attitudes should emerge. In the first stage (grade 1-3), students should, with the help and encouragement of others, "demonstrate curiosity in events around us and in objects related to mathematics; able to participate actively in animating, intuitive mathematical activities" [19, page 14]; note how this emphasises both products and processes. In the second stage (grade 4-6), students should demonstrate "curiosity in objects related to mathematics that have bearings with the surrounding environments; able to participate actively in mathematical activities organized by the teachers" [19, page 14]. In the third stage (grade 7-9), they should be "[h]appy to contact mathematical information in the societal environments; willing to talk about some mathematical issues and topics; able to play an active role in mathematical activities" [19, page 15]. But, they should also "[d]are to confront problems encountered in mathematical activities; have successful experiences in overcoming difficulties independently by oneself and deploying knowledge to solve problems; possess confidence in learning mathematics well" [19, page 15].

Looking at this progress a bit closer and taking a *person* perspective, we see that it is not so much about how the individual experiences mathematics and his or her personal feelings as it is about learning to express (demonstrate) positive attitudes in a pre-determined trajectory. It is not clear if the students should *feel* any intrinsic motivation or positive feelings; if they can *demonstrate* positive behaviors such as curiosity, we could just be looking more at a case of extrinsic motivation. It seems that students should 'show joy' but it is not necessary that they 'feel joy'.

If we instead focus on mathematical products and processes, we see that creativity appears to be connected to both, e.g. in problem solving.

3.2. England

The National Curriculum in England: Mathematics Programmes of Study [7] is divided into three key stages. The stated purpose of the study of mathematics starts by saying that "[m]athematics is a creative and highly interconnected discipline that has been developed over centuries, providing the solution to some of history's most intriguing problems" [7]. Here, creativity is not linked to the individual but more to the subject in itself, using a historical perspective to back the argument. Then the document continues with the way mathematics relates to everyday life and its applications in various areas. And, interestingly, the description ends with the following argument:

> "A high-quality mathematics education therefore provides a foundation for understanding the world, the ability to reason mathe-

> matically, an appreciation of the beauty and power of mathematics, and a sense of enjoyment and curiosity about the subject."

There are several references to *processes* such as *understanding* and *reasoning*, but also aesthetical aspects of mathematics such as 'beauty'. Affective elements are *enjoyment* and *curiosity*, and we could interpret *power* as a motivational factor, although not necessarily intrinsic, for why one should learn mathematics.

The document then moves on to the mathematics content for the different grades. The focus becomes exclusively the subject material and the development of how students should work mathematically.

3.3. Finland

In the Finnish curriculum [31], we can read that the education provided shall develop students' creative and exact thinking; note how this emphasises the individual in the practice. 'Exact thinking' might refer to a *process* more than a *product*, but it is possible to produce such behaviour by mimicking procedures. The document declares that mathematics can be seen from a broad perspective and as a subject it "affects the student's spiritual growth" and her or his ability to act purposefully and interact socially [31, page 158]. Again the focus is on the *person* and the word 'spiritual' could have aesthetical and/or motivational aspects.

We can also see that students are expected to display affective development. In grade 1-2 the goal is students shall "have joy and satisfaction of understanding and solving problems" [31, page 158]. In grade 3-5 the goal for the affective areas has changed; now students shall "have the experience of succeeding in mathematics" [31, page 161]. In the last grades (6-9), students shall "learn how to trust themselves in mathematics" [31, page 163]. The progression in the affective area is from joy to security.

3.4. India

In the Indian curriculum, the first aim in learning mathematics is to develop knowledge about various *products*, but the higher aim is provide an education that encourages children to think and reason mathematically. This includes the "attitude to formulate and solve problems" [20, page 42]. The focus is on the *person* and the affective component, an attitude.

We can find more affective aspects in what are listed as *visions*. The first vision for school mathematics is that "[c]hildren learn to enjoy mathematics rather than fear it" [20, page 43]. Clearly this vision emphasises the positive emotional state and the individual. Though there are also several indications that children should learn *processes*[3] the curriculum returns to the affective factors and their role for mathematics education at several places. The document is explicit in mentioning the importance of encouraging children to freely express thoughts and emotions; this is seen to be a way to avoid copying what the teachers say. Children should develop their own voice. Emotion is one tool, but we can also see that positive affective experiences are important for other reasons:

> "Having children develop a positive attitude towards, and a liking for, Mathematics at the primary stage is as important, if not more than the cognitive skills and concepts that they acquire" [20, page 44].

It is more important that children have the chance to experience that mathematics is joyful than that they learn specific mathematical products such as concepts and procedures. The authors explain:

> "Mathematical games, puzzles and stories help in developing a positive attitude and in making connection between mathematics and everyday thinking" [20, page 44].

Mathematical games, puzzles, and stories are here seen as a tool for increasing positive affect in mathematics education.

3.5. Japan

The Japanese curriculum in mathematics education for elementary school states in the first objectives that "[t]hrough mathematical activities students will [...] (3) recognize the joy of mathematical activities and the merit of mathematical manipulation" [28, page 2]. In this sentence we can find

[3]For instance children should learn "important mathematics: mathematics is more than formulas and mechanical procedures" and "[c]hildren pose and solve meaningful problems" [20, page 43].

connections between positive emotions ('joy') of the individual (*person*) and mathematical *processes* and *products*. It is not clear however, whether manipulation is reduced to a demonstration of rote-learning or it should also encompass problem solving. In any case, there are no further references to the affective side of mathematics in the stated objectives for lower secondary school; it is made clear only that the students shall deepen their understanding, develop fluency, and foster utilization.

3.6. Singapore

The syllabus for primary schools in Singapore starts with a rationale that mathematics "is an excellent vehicle for the development and improvement of a person's intellectual competence in logical reasoning, spatial visualisation, analysis, and abstract thought" [6, page 5]. Instead of focusing only at the engineering side of mathematics, the rationale goes on to state that "[m]athematics is also a subject of enjoyment and excitement, which offers students opportunities for creative work and moments of enlightenment and joy" [6, page 5]. These positive emotions, it is asserted, will work as a motivation for the students "to pursue mathematics beyond the classroom walls" [6, page 5].

There are several aims listed for mathematics education in schools; the following two are about affective domains: "(5) Develop positive attitudes towards mathematics; (7) Produce imaginative and creative work arising from mathematical ideas" [6, page 5]. The affective side is an underlying principle in the framework presented in the syllabus regarding mathematical problem solving, where *attitudes* is a main category for beliefs, interest, appreciation, confidence, and perseverance. Also, affect is influenced by the situation, the practice, which in turn can be a tool for creating positive affect towards mathematics within the person:

> "Students' attitudes towards mathematics are shaped by their learning experiences. [...] Making the learning of mathematics fun, meaningful and relevant goes a long way to inculcating positive attitudes towards the subject. Care and attention should be given to the design of the learning activities, to build confidence in and develop appreciation for the subject." [6, page 9].

3.7. Sweden

According to the Swedish curriculum for grade 1-9, students should have the possibility to develop interest for mathematics and belief in their own ability to use mathematics in different situations [25]. Here the focus is on the student and her or his interest, which could be linked to intrinsic motivation. Besides teaching students to apply mathematics in various contexts and develop a set of competences / abilities, mathematics education should also provide an opportunity for the students to "experience aesthetical values when working with mathematical patterns, shapes and correlation" [25, page 1]. In additional material, the School agency states that there is "an intrinsic value to experience aesthetical values and to solve mathematical problems since they are in themselves stimulating tasks and that problems and solutions have their own beauty" [26, page 8]. The concept of 'beauty' (of problems and solutions) is in most cases a positive phenomenon though clearly subjective; what is beautiful lies in the eyes of the beholder.

Overall, the focus is on the students (*persons*), problems and solutions (*products*) and the process of solving tasks (*process*).

3.8. The United States

In the Common Core Standards for Mathematics, there seems to be no explicit mention of the affective side of the subject [5]. Moving on to the description of the eight practices, the focus is on the use of mathematics and how it is used but not on the personal experience of using it. The situation is the same if you look at the different standards at different grades or through the different mathematical domains. It seems that the focus is on mathematics as a tool.

3.9. Summary: What Can We Learn from Educational Policy Documents?

The different educational texts communicate different aspects of recreational mathematics as part of learning mathematics in the institutions of schools. One country, India, stresses it more by emphasising the relationship between playing games and doing puzzles and the development of positive attitudes towards mathematics. The American standards in comparison, mention nothing about recreational mathematics. Most countries touch upon aspects of recreational mathematics; the common theme is problem solving linked to positive emotions. The students, in a *person* perspective, should experience joy and thereby develop positive intrinsic emotions.

4. Why Recreational Mathematics 2.0?

As a second step, I approach the "Why?" question from an educational historical perspective. To this end, I have done a literature search and surveyed an eclectic selection of texts (books, papers) that would encompass different aspects of recreational mathematics. In presenting my findings, I start with the more contemporary texts, and work backwards through time. In my analysis, I use the same affective concepts as before.

4.1. Recreational Mathematics From Ancient History to Computer Games

As a possible modern take on recreational mathematics, we first consider computer games with mathematical content. Ke in [15] presents a case study where grade 4 and grade 5 students work with mathematics in a summer camp using computer games. The results indicate that students developed more positive attitudes toward math learning through five-week computer math gaming, but there was no significant effect on their mathematical content knowledge or metacognitive awareness development. Playing is fun, but according to the definition we previously established in §2, in order to be recreational mathematics, an activity needs to have an educational component. Similar arguments can be found in [17] where the authors conclude that recreational mathematics can be part of a learning environment that aims to increase positive attitudes towards mathematics, and in such an environment, with its link to motivation, it may in the long run influence students' learning.

This has been noted before. In particular mathematicians who have thought and written about problem solving have often emphasised the value of pleasure. Pólya for instance writes in the preface to his famous book that:

> "a mathematics problem may be as much fun as a crossword puzzle, or that vigorous mental work may be an exercise as desirable as a fast game of tennis. Having tasted the pleasure in mathematics he will not forget it easily and then there is a good chance that mathematics will become something for him: a hobby, or a tool of his profession, or his profession, or a great ambition" [24, pages *v-vi*].

Thus Pólya connects enjoyment with positive intrinsic motivation to do and learn mathematics. He shares this thought with mathematics educators before him. Pierce, for example, writes that besides that puzzles sparks curiosity and desire it also "stimulates the imagination and develops the reasoning power" [23, page 13]. Parker gives examples of recreational mathematical problems when arguing that puzzles are excellent tools for motivating high school students in mathematics [22].[4]

Another argument in favor of recreational mathematics is that it can serve as a tool for relaxation [18]. This might be viewed as a possible factor creating intrinsic, positive motivation to do recreational mathematics.

Trigg [30] stresses that no matter how we view recreational mathematics, one thing is clear: this is not a new phenomenon; recreational mathematics has a long history. Dudley cited in [30] establishes that recreational mathematics goes back to Babylonian tablets and The Rhind papyrus, making this an activity more than 3500 years old. Some problems from these historical texts are presented in [13, 30] as examples. Heefer [13] concludes that many of the same kinds of problems appear in very different cultures and areas, illustrating this with the *sliding ladder problem*, where a ladder of a given length is leaning against a wall and slides from its original position. The fact we could find this problem in the old Chinese mathematical texts, Old-Babylonian tablets, Sanskrit mathematical texts and so on (cf. [13]) indicates the human ability and willingness, through history, to share recreational mathematics independent of culture and geographical area.

4.2. Récréations Mathématiques

We know thus that recreational mathematics has a long history. At the same time there are not many treatises on the educational aspects of recreational mathematics. Now we study in some detail one of the early works that falls in this category: Jacques Ozanam's *Récréations Mathématiques et physiques*. *Récréations Mathématiques* is lauded as a central book in recreational mathematics, a classic that had impact for centuries; see in particular [4, 12, 13, 29]. Therefore I search for educational arguments in the foreword authored by Ozanam.

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[4]But readers might ask: Do students meet this side of mathematics in schools and higher education? According to Anderton and Wright, mathematical students today seldom meet the creative dimensions of mathematics and that "they are missing out one of the oldest, most insightful and abstract of arts" [2, page 93]. If so, recreational mathematics is not part of school mathematics or mathematics taught at university level.

Gaston Tisandier, who was the main editor of 'La nature' wrote that Ozanam was an author of many excellent books, and that, compared to Ozanam's work, Tissandier's was not as 'amusing' [29]. The book itself is a development of earlier versions of *Récréations Mathématiques*. In 1694 there was a new edition with Ozanam as editor, and short after, one edition with Jean-Étienne Montucla as editor. The latter was printed in over twenty editions and grew to four volumes. A hundred years later, in 1769, Guyot took over and then it became an encyclopedia in four volumes with the title *Nouvelles récréations physiques et mathématiques*. Most libraries would list Jean Leurechon as the original author to the first edition of *Récréations Mathématiques* despite there being no indication of this in the book itself [12]. Heefer would like to propose another more likely author, Jean Appier dit Hazelet, based on several clues. For one, in the preface, the author to *Récréations Mathématiques* gives the following instructions to its readers:

> "I have used copper plate engravings for the most needed illustrations to clarify some propositions. I have done so rather than using the more expedient woodcuts where they could have been put on their proper place; nonetheless, using numbering to overcome this minor inconvenience" [12, page 11].

Heefer's conclusion is that the author to this description is a printer and not a Jesuit mathematician or his student.

One third of the problems in *Récréations Mathématiques* are in arithmetic and combinatorics, and most of them originate from *Problemes plaisants* by Claude Bachet [12]. In the preface to the book, Ozanam refers to Bachet and celebrates him. This might be one of the reasons why so many people think that recreational mathematics started with Bachet [12].

According to Ozanam [21], there are three types of problems within recreational mathematics:

1. Number games, e.g. chess;
2. Games of chance, e.g. throwing dice; and,
3. How you move, e.g. archery or pool.

All of these three can be related to mathematics, and we can use mathematics to enhance our chances to win. It is simply about numbers and combinations of these, about masses, and sizes of bodies. Ozanam explains that even though it might look impossible to win, there is always a way. Therefore you should continue to gamble so you can get closer to perfection. His conclusion is that all people should gamble / play: Serious people should gamble / play to have some fun in their life, and others should gamble / play in order to learn mathematics. Mathematics is, according to Ozanam, a part of life, and recreation is really for everyone. Mathematics is also the most joyful activity one can engage in in life and you cannot, should not, prevent people from doing mathematics since it is so joyful.

Just as Bachet, Ozanam wants to introduce pleasure to problem solving. This is in Ozanam's view not a new thing; he is only following the footsteps of wise men. Some of the 'wise men' that Ozanam gives as examples are Pope Léon X who played chess, the kings of Syria who exchanged puzzles with each other, and the ancient Greek teachers. According to the Greeks, once we wake up a child's mind, the child is going to start to think. A child, Ozanam continues, has a very capable brain but it needs to be woken up. Hence, it is as crucial to exercise the brain as it is to exercise the body. According to Ozanam, problem solving is part of life and therefore it is important to do it as a child since if you are surrounded by numbers and problems you are going to manage business and finances better. You are also going to be better prepared for everyday problems. Ozanam compares this to learning to walk. We need to relax more and have fun and you need to love what you are doing in order to relax. The affective part of learning is stressed and intrinsic motivation is reached through positive emotions.

Furthermore, recreational mathematics is for everyone; it does not matter if you are young, old, rich, poor, a man or a woman:

> "Mais les jeux d'esprit sont de toutes les saisons & de tous les âges; ils instruisent les Jeunes, ils divertissent les vieux, ils conviennent aux riches, & ne font pas au-dessus de la portée des Pauvres ; les deux Sexes s'en peuvent accommoder sans choques la bienséance" [21, page *v*].[5]

This could be been seen as a bit surprising since it was written about a hundred years before the French revolution!

[5]Roughly: "But the mind games are for all seasons and for all ages; they teach the young, they entertain the old, they are agreeable to the rich, and they are not unreachable for the poor; both sexes can do them without shocking what is [considered] propriety."

Ozanam continues with an example. Roman emperors Diocletin and Constantin both considered mathematics dangerous. Mathematicians were viewed as magicians, i.e. criminals, and were punished with the same punishment according to title 17, book 9, of the code of Justinian. This was due to ignorance, in Ozanam's view. Mathematics got a bad reputation because of charlatans who used mathematics to fool people. The problem, Ozanam writes, lies within the ignorant people; they need to educate themselves and it is their own fault if they are too lazy to do the work that is needed [21]. Ozanam's analysis of the situation is that when there are too many people who don't know something, there is a tendency to blame the ones who do know. It is therefore easier to accuse people of being magicians and witches than trying to understand. Ozanam wants to educate all people to understand this "mathematical magic".

What Ozanam is describing is a type of democratic mathematical empowerment similar to that presented by Ernest in [8]. Learning mathematics has an impact on the person as an individual but also in a wider social context. Looking at it at a group level, social empowerment has been studied under the heading of *critical mathematics* (cf. [27]). When Ozanam says that recreational mathematics is for everyone, one reason for this is to empower people.

4.3. Summary: What Can We Learn from Historical Texts?

The two common themes in the modern policy texts and the historical texts I reviewed are the following:

- Affective aspects are important to the learning of mathematics, and
- Recreational mathematics can be an effective tool for nurturing students' affective development.

(Alternatively, problem solving should be fun and students should have the opportunity to experience this kind of fun; both are ideas shared by Ozanam [21], Pólya [24], and present time educators.) One can view the utility aspect of recreational mathematics in several layers. Through history, recreational mathematics has played a role both as entertainment and as a means to transfer knowledge. Ozanam [21] pushes this idea further and talks about education for all people, to prevent ignorance and acting based on ignorance. This is the same basic idea shared in theories of mathematical empowerment and critical mathematics.

5. Conclusion: What is the Common Ground?

In this report I aimed to explore, from an education perspective, different reasons why one should engage in recreational mathematics, using policy documents and historical texts. The research question I posed was: "In what ways do modern policy documents reflect historical thinking about recreational mathematics?" The common theme that emerged is that mathematics should be fun. Most countries in their policy documents stress problem solving and positive emotions, and the idea that students should meet mathematics in this way is found in modern [2] and historical texts [21, 22, 24]. Positive emotions are connected to positive intrinsic motivation both in curricula and in the historical texts I reviewed.

Recreational mathematics can also be seen as a tool to educate people, *all* people, and not just a selected elite. This is both on a personal level [20] but also on group level [21, 27]. The controlling of mathematical knowledge is equal to power. Recreational mathematics is then not only for fun or a nifty educational tool to learn mathematics, but also a way to reach mathematical empowerment.

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