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A mathematical stimulus program for an educational intervention with students at risk of social exclusion

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Abstract

The research investigates a mathematical stimulus program for an educational intervention with students at risk of social exclusion. Reducing the school failure of students is one of the goals of current inclusive education. Particularly, mathematics is a discipline in which adolescents demonstrate a greater degree of failure worldwide. In this research, a mathematical stimulus program employing STEAM (Science, Technology, Engineering, Art, and Mathematics) activities for adolescents at risk of social exclusion due to family causes is analyzed. The aim is to assess the mediational and affective suitability of the program. The sample consisted of 68 students from three secondary schools. A mixed methodology was used, employing quantitative analysis techniques for the beliefs and satisfaction questionnaires applied. The Theory of Didactic Suitability was also employed, along with semi-structured interviews for qualitative analysis. The results indicate that pleasure and effort constitute a single factor among these students, and a positive correlation is obtained between how interesting an activity seems to the students and what they learned, and between their learning and the novelty of the content. The descriptive analysis shows that 96% of the students considered the activities to be interesting; with 85% stating that they had learned a lot. The recordings and interviews show that the students felt at ease carrying out the activities and that a significant change in their attitude towards mathematics took place. In conclusion, the presence of at least 87% of the indicators in all activities gives the program a high degree of mediational and affective suitability. Furthermore, the role of mediational suitability in this context stands out and has a direct influence on affective suitability.

Keywords: Affect, Didactic suitability, Mathematics, Secondary, Social exclusion, STEAM.

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1. Introduction

In recent years, several studies and reports [1, 2] have indicated an increase in adolescents at risk of social exclusion. The term "social exclusion" is used to refer to those sectors of society that are vulnerable due to their specific social conditions and are marginalized as far as certain rights relating to work, education, and culture are concerned [3, 4]. Exclusion during adolescence constitutes a process of social injustice, inequality of opportunities, and disadvantage with regard to the peer group and is particularly evident in schools. In most cases, such students demonstrate a great lack of interest in the educational system, thereby leading to academic failure [5-9]. The causes of this low level of achievement are mainly of external origin, linked to the social environment in which these young people live and their family situation [10-13]. The family and academic circumstances of students at risk of social exclusion are analyzed in different contexts, focusing on working on emotions and attitudes towards life and society without placing emphasis on the relevance of these aspects in the students' studies as a form of preventing social exclusion [14].This failure becomes more visible in specific knowledge areas, such as mathematics, which a lot of students find difficult in general and which do not generate a positive attitude towards the learning process. Research by Cueli, et al. [15]; Cézar [16]; Hill, et al. [17]; Lamana-Selva and Peña [18]; López-Chao, et al. [19] and Vukovic, et al. [20] shows the negative relationship that exists between, for example, mathematical anxiety and the level of achievement attained in this subject.

Interest in the importance of the affective domain in the learning of mathematics has increased significantly since the work of McLeod [21] and McLeod [22]. However, it still has no clear and universal definition [23-26]. According to Gomez-Chacon [26], the affective domain is taken to be the ongoing and permanent educational process that aims to strengthen emotional and cognitive development for the integral development of the individual. It is interpreted as attitudes, beliefs, and emotions towards mathematics. This author also introduces the concept of global affect in order to indicate the study of the affective domain, which takes into account students' social reality and socio-cultural context [27]. Subsequently, DeBellis and Goldin [25] provided a tetra-dimensional perspective according to which affect is made up of beliefs, attitudes, emotions, and values.Several investigations indicate a strong relationship between the affective and cognitive domains, with the two forming an inseparable whole. The influence of the affective domain on the cognitive is key to explaining the learning process [23, 26, 28-31], which is of greater relevance in problem solving [32-37]. Different authors and reports [15, 18, 26, 38-43] point out that this fact can explain the problems related to student failure in mathematics. The lack of stimulus and motivation among students results in an unpleasant perception of mathematical tasks, thus having an impact on their academic performance.

The type of environment that the students who are at risk of social exclusion live in should inform the educational response that schools provide. Consequently, no personal or social circumstance can be a motive for discrimination when organizing educational attention for pupils. Therefore, schools should offer a response to compensate for the individual differences of all pupils within the framework of the principles of normalization and inclusion [44, 45]. Authors such as Attard and Holmes [46],Kajander, et al. [47] and Mowery [48] state that the use of technological tools helps to increase the participation of these at-risk students in mathematics classes by increasing their interest in the subject. Mowery [48] compiled the strategies suggested by several authors to increase the participation of such students, including: incorporating movement into the classroom whenever possible, thereby reducing stress and reinforcing the increase of neuronal metabolism; proposing challenges that are achievable in order to prevent loss of interest and boredom among students; and fostering open classes to enable these students to express themselves with complete freedom among their teachers and classmates. Furthermore, programs such as school-to-work, which places students in the working world in order to demonstrate the usefulness of mathematics, are presented. Hornung [49] proposes encouraging interdisciplinary work, integrating mathematics and the sciences within a real-world context. These authors clearly state the need to make use of teaching and learning resources that stimulate pupils and offer a globalized approach, always fostering the use of a collaborative methodology and the quest for research via curiosity. In this regard, STEAM activities, which combine interdisciplinary work, can provide a response in order to stimulate learning and interest in mathematics among adolescents at risk of social exclusion, as seen in Cardenas et al. [50]. Although the benefits of including these types of strategies for working with students at risk of exclusion are wellknown, they are not normally taken into account when planning teaching and learning processes in schools. The support received by these pupils is normally focused on reinforcing curricular contents [31, 51-54] without taking into account the affective domain. Bearing all of this in mind, the present study presents the analysis of an intervention program focused on mathematical stimulus via STEAM activities carried out among adolescents at risk of social exclusion due to their family situations. These situations include homeless families, families without economic resources, broken homes, and situations of child abuse or neglect. Adolescents who belong to such families are often marked by academic failure, which occurs when they drop out of school due to a lack of interest in and expectations of school. Based on the Theory of Didactic Sustainability [55], which calls for studying six suitabilities, the main goal of this paper is to judge how well the teaching process meets those requirements. The present study focuses on the analysis of two of these suitabilities (mediational and affective suitability), and it is shown that proposals based on encouragement can modify the affective domain of mathematics in this group, laying the groundwork for the subsequent study of their academic performance. Preference has been given to these two suitabilities due to the fact that performance in problem solving is affected by students' beliefs, emotions, and attitudes towards this subject and by the material conditions in which the activities are carried out [19, 29, 32, 56]. Therefore, in this context, it is considered that the first step when studying the didactic suitability of the program is to begin by analyzing its mediational and affective suitability.

2. Didactical Suitability Theory

The Didactics of Mathematics, approached as a design science [57], directs its focus towards crafting processes and resources to enhance the teaching and learning of mathematics. In tandem with this approach, the Didactical Suitability

Theory (DST) [55, 58, 59] has emerged. This theory, conceived based on the concept of didactical suitability, facilitates a transition from descriptive didactics (which involves describing, interpreting, and/or explaining teaching and learning processes) to normative didactics (which involves evaluating and improving these processes).The development of the notion of didactical suitability takes into consideration current trends in mathematics education, the principles outlined by the NCTM [60], and contributions from various theoretical perspectives within the realm of mathematics education [58, 61]. Drawing inspiration from Godino, et al. [59], the didactical suitability of a teaching process is defined as the extent to which the process embodies specific characteristics aimed at achieving alignment between the individual meanings constructed by students (learning) and the intended or implemented institutional meanings (teaching). This evaluation takes into account the contextual factors in which the said process unfolds.

Didactical suitability is a multi-dimensional construct that can be decomposed and articulated coherently into the following six partial suitabilities or criteria of didactical suitability [59]: epistemic, cognitive, interactional, mediational, affective, and ecological. Epistemic suitability refers to the degree of representativity of the institutional meanings implemented with regard to the meaning of reference. Cognitive suitability indicates the degree of suitability of the meanings implemented in relation to students' potential development and the degree of the personal meanings achieved with respect to those sought or implemented. Interactional suitability indicates the degree of identification of semiotic conflicts and the resolution of conflicts that arise during the teaching process. Mediational suitability is related to the degree of suitability of material and temporal resources used during the teaching process. Affective suitability indicates the degree of affectivity (attitude, emotions, values, and beliefs) developed by students throughout the instructional process. Ecological suitability refers to the degree to which the study process fits the context in which it is carried out. Moreover, these partial suitabilities are, in turn, organized into components. Figure 1 shows an illustration of what has been described above.

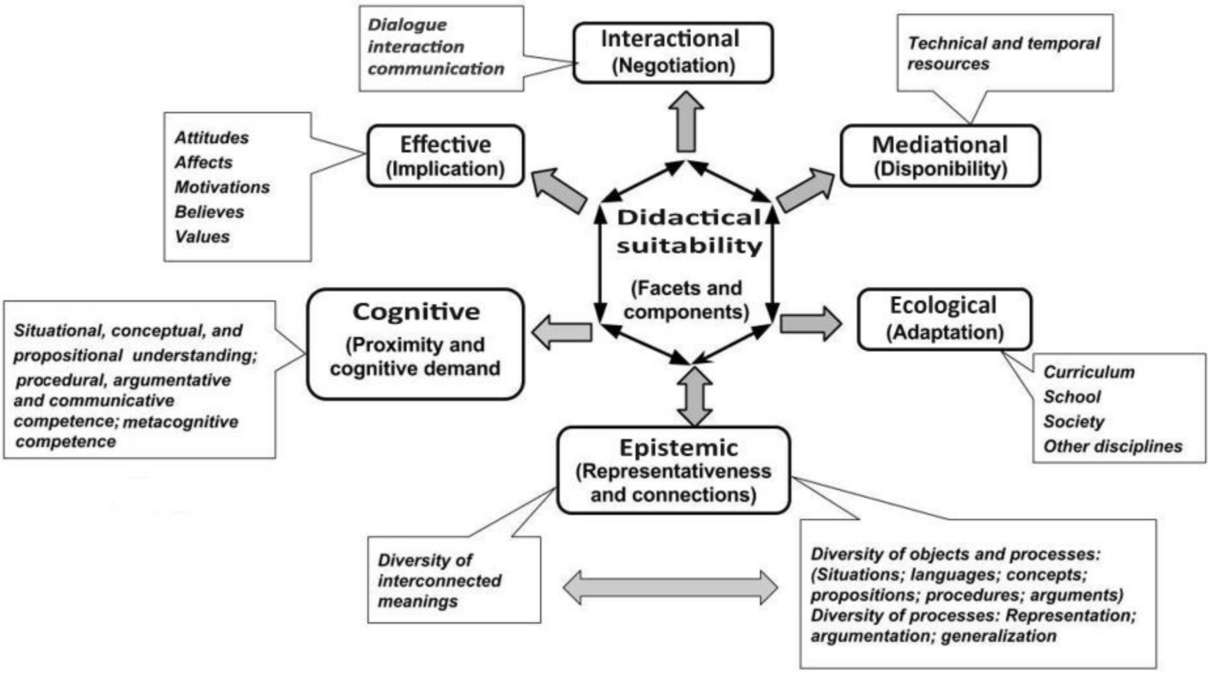

Figure 1.
Facets, components and basic didactical suitability criteria.
Note: Godino, et al. [59].

A teaching and learning process is considered suitable when a balance is achieved between the different criteria of suitability. This balance implies that the criteria should be taken into consideration jointly, giving a specific weight to each one according to the context in which the teaching and learning process arises and its relationship with this process. Thus, the notion of suitability attributes a fundamental role to the context, and, therefore, the didactical suitability of a process does not depend on prior consensus in the community alone but also, to a great degree, on the conflict that the suitability criterion generates with the context and with the other criteria [61].

Neither the criteria nor their components are directly observable and, therefore, it is necessary to define observable, indicators that make it possible to evaluate the degree of suitability of each of these criteria. Beltrán-Pellicer and Godino [23], Godino [58] and Breda et al. [61] present systems of indicators for the different partial suitabilities and for the interactions between them, which serve as a guide for the analysis and evaluation of didactical suitability. Given that this paper only analyzes mediational and affective suitability, Table 1 shows the indicators and components of these suitabilities(with MI referring to mediational indicators and AI to affective indicators).

Table 1.
Components and indicators of mediational and affective suitabilities.

Suitability	Components	Indicators
Mediational	Material resources	MI1. Manipulative and IT materials are used, which make it possible to introduce good situations, languages, procedures, and arguments adapted to the contents. MI2. The definitions and properties are contextualized and motivated using specific situations, models, and visualizations.
	Number of pupils, timetable and classroom conditions	MI3. The number and distribution of the pupils make it possible to carry out the intended teaching. MI4. The timetable is appropriate. MI5. The classroom and the distribution of the pupils are appropriate for carrying out the intended teaching process.
	Time	MI6. The face-to-face and non-presential time is sufficient for the intended teaching. MI7. Sufficient time is dedicated to the most important contents. MI8. Sufficient time is dedicated to the contents that present the most learning difficulties.
Affective	Interests and necessities	AI1. The tasks are interesting for the pupils. AI2. Situations are proposed that make it possible to evaluate the usefulness of mathematics in daily and professional life.
	Attitudes	AI3. Participation, perseverance, and responsibility are promoted. AI4. Argumentation in situations of equality is fostered, valuing the argument itself and not who argues it.
	Emotions	AI5. Self-esteem is promoted. AI6. The rejection, phobia, and fear of mathematics are avoided. AI7. Aesthetic qualities are highlighted. AI8. The accuracy of mathematics is highlighted.
	Beliefs	AI9. The teaching and learning process is built gradually based on the students' beliefs.

As illustrated in the table, the characterization of affective suitability [23] relies on the tetrahedral model proposed by DeBellis and Goldin [25], which encompasses key descriptors within the affective domain: emotions, attitudes, beliefs, and values. Emotions are defined as swiftly changing feelings experienced consciously or emerging pre-consciously or unconsciously during mathematical activities. Ranging from subtle to intense, emotions are intricately woven into local and contextual dimensions, influencing attitudes. Attitudes represent predispositions towards specific sets of feelings (positive or negative) in distinct mathematical contexts, exhibiting a moderate stability that denotes an interactive equilibrium between affect and cognition. Additionally, the attitude towards mathematics is regarded as a lens for interpreting the interplay between emotions and beliefs [62]. Beliefs involve the ascription of some form of truth or external validity to a system of propositions or other cognitive configurations. Emotions and attitudes both influence beliefs, which contribute to their remarkable stability. Values pertain to personal truths or commitments that are deeply rooted within individuals. Serving as motivators for long-term decisions or as benchmarks for short-term priorities, values play a significant role in shaping the affective landscape.

Beliefs and values are closely related, and, on occasion, their separation may not be possible. Based on the relationship that exists between the descriptors of affect [62] and their cyclical interaction with learning [26], this paper contemplates [63] the reconceptualization and new categorization of beliefs.

3. Materials and Methods

As mentioned in the introduction, research carried out proposes that one way of stimulating students and thereby modifying their attitude towards mathematics is to awaken positive emotions by way of employing motivating activities and resources. This directly relates the affective domain to the means used in the teaching process. This paper analyzes a program based on mathematical stimulation via STEAM activities for teenagers at risk of social exclusion due to family reasons. Two research questions have guided this study: Are the material resources and the timing employed in the stimulus program appropriate for working with students at risk of social exclusion due to family reasons? Does the program promote a positive attitude towards mathematics, which is translated into motivation and interest? Within the framework of the DST, these questions aim, respectively, to analyze the mediational and affective suitability of the program. In order to achieve this, the following specific objectives have been proposed: to analyze the beliefs about mathematics of adolescents at risk of social exclusion due to the fact that, according to the theoretical framework, these beliefs should guide the entire intervention process; to identify which mediational and affective indicators are shown in the intervention of each activity designed; and to explore the trend of these students 'academic performance in their everyday mathematics class.

A mixed methodology has been employed for this research, which is specific to the analysis of social contexts such as this study. Quantitative and qualitative tools and techniques have been used for the collection and analysis of the data [64, 65].

An interpretative approach has been followed in which the researchers are participating observers, directing the intervention in the classroom, and creating a record of the activities by way of video recordings and a field diary.

3.1. Population and Sample

The research was carried out over the course of two school years (2017-2018 and 2018-2019) in three secondary education schools in Spain. The schools are situated in semi-urban areas where a sizable population segment runs the risk of social exclusion. The students enrolled in the program underwent a selection process conducted through a collaborative meeting involving the schools counsellors, responsible for assessing and addressing the educational and familial needs of each pupil throughout their learning journey, mathematics teachers, and the researchers. The selection criteria encompassed three key considerations: firstly, affiliation with vulnerable families, which included those classified as dysfunctional or lacking resources, and adolescents residing in juvenile facilities or under the care of social services; secondly, a demonstrated low academic performance in mathematics coupled with a negative attitude towards the learning process of mathematics; and thirdly, educational challenges linked to their family situation rather than cognitive capabilities or any underlying disorders. This joint assessment ensured a targeted selection process to address the specific needs of the participating students. Once the definitive selection had been made, a meeting was organized with the families or legal guardians in order to explain the program to them. The final sample consisted of 68 students at risk of social exclusion ranging from 12 to 15 years of age.

3.2. The Intervention Program

The intervention program consisted of 14 activities, implemented biweekly outside of school hours across three secondary schools. The design of these activities adhered to recommendations from various authors [15, 28, 48], emphasizing experiments that empower students to question, investigate, and discover within a globalized framework and a collaborative environment. Each activity adopted an interdisciplinary approach, addressing mathematical contents via the STEAM methodology [66]. While most of these contents aligned with the school curriculum, they were applied to real and novel contexts, fostering active student participation. In accordance with recommendations from the school counsellors and taking into account the characteristics of the students, such as a short attention span and disruptive behavior, each activity was structured to last one hour. A detailed account of the development of some of these activities can be found in Blanco, et al. [67] and Blanco, et al. [68]. The intervention process focused on promoting interaction through verbal communication with students [40]. In addition to serving as observers, a counsellor and a mathematics teacher from each school were present when two researchers facilitated this engagement. Table 2 outlines the activities related to STEAM subjects and describes the mathematical contents embedded in each activity.

Table 2.
Activities of the intervention program.

A#	Name of activity	STEAM subjects	Mathematical content
A1	Mathemagic	Mathematics and art	Elementary operations, numbering systems, and mental calculus.
A2	A cheeky band	Mathematics and physical education	Cylinder, torus, sphere, face, edge, single-sided surfaces, inner face, outer face, and surfaces with holes.
A3	Mathmusic	Mathematics and art	Bayes' theorem, probability, random, fractions, equivalences, and units of time measurement.
A4	The combinatorics of Carnaval	Mathematics and social sciences	Problem solving and combinatorics.
A5	What happens if we mix?	Mathematics and chemistry	Estimation of quantities, control of variables,bar and sector graphs, percentages, and handling of measuring instruments.
A6	Mathematics in the air	Mathematics and physics	Units of the international system of measurement, graphs, and measures of central tendency.
A7	Discovering π	Mathematics and natural sciences	Units of the international system of measurement, arithmetic mean, length and diameter of the circle, and the number π.
A8	A world of quadrilaterals	Mathematics, art and technology	Recognition, classification, and construction of quadrilaterals, concave, convex and convex, conjecture, non-conventional units of measurement, and handling of the physical and virtual geoboard.
A9	Polyhedrons	Mathematics and technology	Three-dimensional figures, classification of polyhedron, regular polyhedron, concavity, and convexity.
A10	Mandalas	Mathematics and art	Perpendicular line, mediatrix and bisector, polygonal and non-polygonal figures, inscribed and circumscribed figures, symmetry, rotation, and translation.
A11	The NBA (National Basket Association)at school	Mathematics and physical education	Percentages, mean, mode, and median.
A12	Reading paintings	Mathematics and art	Cartesian coordinates, estimation, and geometric figures.
A13	Dynamic geometry	Mathematics and technology	Euler's line. Construction of figures of equal area and different perimeters.
A14	Mental agility with Kahoot	Mathematics and technology	Arithmetic operations.

3.3. Tools for Data Collection and Analysis

The process of collecting and analyzing the data was carried out simultaneously throughout all the activities of the program in all the schools and in the two academic years (2017-2018 and 2018-2019). The tools employed for the collection of quantitative data were a belief questionnaire, a satisfaction questionnaire, and assessment records. The beliefs questionnaire, applied individually on the day that the stimulus program started, was adapted for this context from the MRBQ (Mathematics-Related Beliefs Questionnaire) by Diego-Mantecón [63], making it possible to establish relationships between the affective domain and the sociocultural context of the pupils and examining in depth the repercussions on their learning of mathematics. The questionnaire consisted of 49 statements corresponding to 12 dimensions (traditional learning, self-concept, importance of marks, constructive learning, Usefulness in everyday life, anxiety, elaboration strategies, effort, usefulness in professional future, self-efficacy, procedural strategies and pleasure) employing a Likert-type scale for the responses. The satisfaction questionnaire had the objective of enabling the pupils to evaluate the content, and development of each activity and included questions on the difficulty of the activity, interest, the relationship with other subjects, novelty of the contents, and the students' perception of what they had learned. A 4-point Likert scale was applied at the end of each activity. The assessment records reflect all the numerical marks (academic performance) of the pupils in the subject of mathematics and were provided by the students' mathematics teachers over the course of the two academic years. In order to analyze the information originating from the different questionnaires, the statistical packages SPSS and ANOVA (Analysis of Variance) were employed, making it possible to obtain descriptive results and correlations between variables, respectively.

To collect the qualitative data, five tools were used: video recordings; semi-structured interviews with the adolescents; semi-structured interviews with the teachers and school counselors; and the field diary, which made it possible to complement and contrast information on the data collected via the other tools. The video recordings, along with the field diary, were the data collection elements used in all activities and semi-structured interviews. The semi-structured interviews were carried out with the pupils, teachers, and counselors once the full program had been completed. In this way, they had time to detect changes in the variables analyzed and to reflect upon them. The interviews with the adolescents took place in small groups and lasted between 40 and 50 minutes, depending on the fluidity of the answers. One block of questions was related to the development and management of the program and another block was about how the students felt when carrying out the activities as far as the freedom to ask and respond with confidence was concerned. Last of all, the interviews with the school counselors and mathematics teachers were carried out for duration of 20 minutes. These interviews included questions focused on observation in the classroom of the students' attitude towards mathematics and the manifestation of their degree of interest and motivation.

The transcriptions of all the visual records (activities and interviews) were analyzed using ATLAS.ti, collecting extracts of verbal language that showed evidence of emotions, attitudes, and values. Likewise, along the lines established by Beltrán-Pellicer and Godino [23] and Knapp et al. [69], the qualitative analysis of the affective information was complemented with elements of non-verbal language, such as facial expressions, gestures, postures, and movements, from watching the videos. All of the above made it possible to complete the more normative qualitative analysis employing the indicators of mediational and affective suitability of mathematics teaching and learning processes provided by Beltrán-Pellicer and Godino [23] and Godino [58], shown in section 2.

Table 3 provides a brief outline of the data collection tools, the time and moment of their application, the sample collected with each of the tools, and the analytical tool applied.

Table 3.
Data collection and analytical tools, temporality and sample.

Data collection tool	Temporality	Sample	Analytical tools
Beliefs questionnaire	Beginning of the program (30 minutes)	68	ANOVA
Video recordings	Each activity (60 minutes)	39	Mediational and affective suitability indicators and ATLAS.ti
Field diary	Each activity (60 minutes)	39	Mediational and affective suitability indicators and ATLAS.ti
Satisfaction questionnaire	End of each activity (5 minutes)	270	SPSS
Assessment record	Each term	68	SPSS
Interviews adolescents	End of the program (40-50 minutes)	3	Mediational and affective suitability indicators and ATLAS.ti
Interviews teachers	End of the academic year (30 minutes)	9	Mediational and affective suitability indicators and ATLAS.ti
Interviews school counselors	End of the academic year (30 minutes)	5	Mediational and affective suitability indicators and ATLAS.ti

4. Results

The results are shown in relation to the specific goals of the research, which were to look at the teens who were at risk of being excluded's beliefs about math, find out what affective and mediating factors show up in each activity, and find out how well these teens do in their regular math classes outside of the programme.

4.1. Beliefs Regarding Mathematics of Adolescents at Risk of Exclusion

Based on the 12 dimensions of mathematical beliefs contained in Diego-Mantecón's [63] model, the factor analysis techniques applied to the data make it possible to group the 49 items of the questionnaire into eight factors, identifying the representative items for each of them. These factors, which explain 69% of the variance of the data and possess a high degree of consistency, indicate that dimensions such as pleasure and effort are strongly related, forming a single factor. Self-efficacy and anxiety also form a single factor. Dimensions such as beliefs regarding the usefulness of mathematics, the pupils' marks, and self-concept correspond to a single factor. The highest and most significant correlation is presented by the factor 'pleasure and effort' with the factor associated with self-concept, which indicates that the higher the level of pleasure towards mathematics and the greater capacity of effort, the better pupils' self-concept is, and vice versa. Furthermore, these two factors (pleasure, effort, and self-concept) have a moderately positive correlation with academic performance (correlation coefficients $r=0.437$ and $r=0.461$, respectively).

4.2. Mediational and Affective Indicators Identified in Each Activity

Table 4 displays the signs that correspond to the parts of emotional and mediatory suitability that were shown in each of the activities created for the stimulus program in the context of inclusion. The presence of each indicator was decided based on the triangulation of data (interviews with pupils, teachers, and counselors, field diaries, video recordings, and satisfaction questionnaires). Their presence is indicated with a 1 when there is verbal, corporal, or written evidence in at least two of the different tools that reflect that indicator. For example, indicator AI1 is reflected in the semi-structured interviews with the students, in the satisfaction questionnaires for each of the activities, and in the video recordings. A mark of 0 is awarded if there is no evidence of that indicator in any of the tools that reflect it.

The material resources component was present in all of the activities carried out in the program (MI1), in both manipulative material (packs of cards, odometers, laboratory material, die-casts, geoboards, musical instruments, felt, and balloons) and technological material (applications, calculators, tablets, computers). Over the course of the activities, work was carried out on mathematical concepts and properties, such as systems of numeration in the application of magic tricks (A1) and in other areas (art, sciences, technology), such as chemical reactions for separating colors (A5). Specific models (MI2) were used when working with quadrilaterals (A8) such as geoboards and die-casts for working on the properties of polyhedrons (A9). Data was collected and handled in several activities in order to take measurements of length (A7, A8, A11) or quantity (A7).

The structure and design of the program considered the components of the number of students, timetable, and classroom conditions to be essential aspect. Thus, its indicators are shown in all of the activities. The work was always carried out with pupils selected according to their necessities deriving from their social characteristics, and groups were formed of 12 pupils or less to enable collaborative work both in the group as a whole and in small groups (MI3). All activities took place in the afternoon outside of the school timetable (from 4:30 PM to 5:30 PM) in order to facilitate attendance (MI4). One key aspect in the design of the program was the choice of different spaces adapted to the needs of each activity proposed (ordinary classroom, hallways, laboratory, computer classroom, assembly hall, gymnasium). Carrying out experiments in the laboratory (A5) or flying planes in open spaces (A6) enabled the pupils to perceive the teaching process (MI5) in a real context.

The distribution of the time component was regularized according to the pupils' needs in each of the activities. All of the activities lasted for 60 minutes, which, in most cases, was considered sufficient to maintain attention and motivation (MI6) in this age range. Even so, in activities A3 and A5, the time of the activity ran short, as can be observed in the table. During the process of the activities, the researchers, as participating observers, emphasized the most important contents (MI7). However, if difficulties arose (MI8) in other secondary contents, time was prioritized in order to resolve them. This occurred repeatedly in all year groups in activities A3 and A7.

Within affective suitability, one of the main components in the design of the program related to interests and necessities. All of the activities were designed with the intention of making them interesting to pupils (AI1), and connecting them with real-life situations (AI2). However, in the implementation of some of the activities, the latter indicator was not always demonstrated. The analysis of the interviews and the results of the satisfaction questionnaires show that all of the activities obtained a high percentage of interest for the pupils, even those in which the connection with the real world was not so direct (A9, A13). These results were complemented by the data obtained from the 270 satisfaction questionnaires on an ascending Likert-type scale of 0 to 3, which showed an average of 2.57 for the question of whether the pupils considered the activities to be interesting, while the average was 2.28 when asked how much they had learned. A total of 96% of the pupils stated that they found the activities quite or extremely interesting, and 85% maintained that they had learned quite a lot or a lot (both in the same proportion).

The STEAM methodology employed in the development of the activities fosters participation and responsibility with the surrounding environment (AI3). The activities fostered participation by encouraging pupils to express themselves freely without fear of committing errors or giving an invalid answer (AI4). The homogeneity of the sample (curricular level and social situation) led to all of the pupils responding spontaneously and without fear of being judged for their level of knowledge. During the course of the activities, the following were detected: errors in the taking of measurements and calculations (A3 and A7); a lack of knowledge of concepts (A4 and A13); a lack of knowledge of properties (A9 and A8); and a lack of accuracy (A2 and A8). The program is intended to create a climate of well-being for these pupils in which making mistakes is considered to be something natural and is always seen as a learning opportunity. On the other hand, care for and upkeep of the material employed in the different activities, along with respect for common spaces, was clearly shown in activities A6, A5, A9, A13, and A14.

As far as the emotional component is concerned, self-esteem (AI5) was promoted in all of the activities, as can be observed in the video recordings and in the interviews. In the majority of the activities, work was carried out on contents of which the pupils already had knowledge. Working in groups helped them feel more at ease if they couldn't remember. It was observed, particularly in the first activities, that some pupils were afraid of responding or using some of the procedures (AI6) to avoid expressing their insecurity. Furthermore, occasional situations of rejection towards certain contents (music) or resources (computers) arose, which were resolved with individualized assistance for the pupil involved. As the program advanced, this fear and rejection disappeared. On the other hand, the qualities of aesthetics and accuracy of mathematics were not presented equally in all of the activities. As can be observed in Table 4, some of the activities emphasized the evaluation of the importance of aesthetics (AI7) more than others. Activities were presented to work on visual aesthetics (A4, A9, A8, A10, and A13), auditive aesthetics (A3), and numerical aesthetics (A7). As far as highlighting the accuracy of mathematics is concerned (AI8), the evidence shows that, with the exceptions of A7 and A9, this was achieved in all of the activities. Finally, the teaching and learning process of all of the activities was built gradually based on the students' beliefs (AI9), as described in section 4.1.

Table 4.
Matrix summarizing the presence of indicators of mediational and affective suitability in the activities of the program.

Indicator	**Number of activity**													
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**	**A12**	**A13**	**A14**
MI1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
MI2	1	1	0	1	1	1	1	1	0	1	1	1	1	0
MI3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MI4	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MI5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MI6	1	1	0	1	0	1	1	1	1	1	1	1	1	1
MI7	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MI8	1	1	1	1	1	1	1	1	1	1	1	0	1	1
AI1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AI2	1	1	1	1	0	1	1	0	0	1	0	1	0	1
AI3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AI4	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AI5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AI6	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AI7	0	1	1	1	0	0	1	1	1	1	0	0	1	0
AI8	1	1	1	1	1	1	0	1	0	1	1	1	1	1
AI9	1	1	1	1	1	1	1	1	1	1	1	1	1	1

4.3. Academic Performance

Figure 2 shows the average marks (on an ascending scale of 0-10) obtained by the pupils of each school in the subject of mathematics in each term of the two academic years analyzed. A growing trend can be observed in the average marks over the course of the academic year. If the data of the first term is compared with those of the third, it can be stated that the increase in the average marks moves within a range from 0.8 points to 1 point. 43% of the pupils passed in the first term, while in June this percentage rose to 67%, and in September 88% of the pupils achieved a pass mark in the subject.

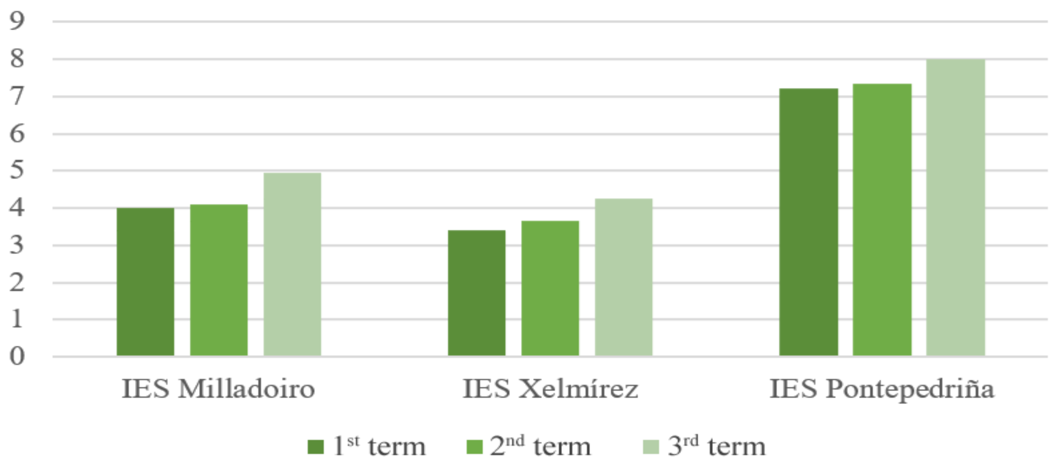

Figure 2.
Evolution of the academic performance of students throughout the 2018/2019 academic year.

5. Discussion

According to the theoretical framework [23], the teaching and learning process carried out in the program was built taking into consideration the beliefs of the students at risk of exclusion (AI9), as these came into play independently of whether a problematic situation arose or not. The factor analysis of the beliefs questionnaire indicates that the dimensions of ‘pleasure’ and ‘effort’ make up a single factor. Therefore, if it is desired that these students make an effort, the activities should be enjoyable for them, which is not in line with the results obtained by Diego-Mantecón [63] with students who were not at risk of exclusion. The results deriving from the beliefs questionnaire show that the pupils’ academic performance in the learning of mathematics maintains a positive correlation with the factors ‘pleasure and effort’ and ‘self-concept.’ The descriptive analysis for these two factors shows that only 22% of the pupils were in disagreement with the fact of liking mathematics and making an effort in this subject. However, at the same time, only 26% responded positively with regard to self-concept. This would indicate that self-concept can be a good way of seeking an improvement in academic performance, although, as Aguilar et al. [70] and Goldin et al. [28] state, there is a high degree of difficulty in working on self-concept. Furthermore, 75% of the pupils agreed or strongly agreed that mathematics is useful, which led to the fact of not placing so much emphasis on the activities of the program to reinforce this aspect (AI2). On the other hand, 63% of the pupils did not express a clear position with regard to anxiety and self-efficacy. These results are in line with the study by Wang et al. [43], which observed modest negative associations between mathematics and performance in mathematics among participants with low motivation intrinsic to this subject. These two factors, along with self-concept, are of great importance as they may not materialize in the same way depending on the context to which the pupil belongs. Some recent studies have put the spotlight on this issue [11, 19].

The design of the activities (mediational suitability) was carried out considering the correlations between the factors described in the previous paragraph. The results of the program show that the degree of correlation that exists (positive moderate) between how interesting an activity appears to be to the students and how much they consider that they have learned reinforces the idea that mathematical stimulus can improve pupils’ self-concept and self-efficacy and, therefore, their learning. Furthermore, a high degree of correlation was obtained between what they consider that they have learned and how original the content of the activity is ($r = 0.804$). There was also a moderate correlation between what they learned and its difficulty ($r = 0.504$). It can be deduced, therefore, that this did not suppose an obstacle for the pupils’ self-concept with regard to their learning to be high and positive. The results show that the activities in which the pupils considered that they learned most were precisely those that they considered to be more difficult and had more original contents (A2 and A4). This suggests that some activities of the project should be reformulated to include new mathematical content with a certain degree of difficulty. It also demonstrates that, given the particular characteristics of our sample, the focus of attention was placed on the attitude towards mathematics rather than on mathematical attitudes, as there was more of a link with the affective domain when referring to the evaluation, appreciation, and interest in this subject and its learning [23, 24, 62].

The triangulation of the data carried out conferred a high degree of mediational and affective suitability to the stimulus program. If all of the indicators are considered with the same weight and the percentage of indicators manifested over the total is taken into account, an average of 94.6% and 91.1% are obtained for mediational and affective suitability, respectively. On the other hand, the qualitative analysis has shown that mediational suitability is strongly linked to affective suitability. The design of the activities contemplating resources, workspaces, and activities that encompass different mathematical contents immersed in real contexts along with other disciplines (MI1) stimulated the pupils’ interest (AI1) and favored their self-esteem (AI5). The same is true of the structure of the program: the distribution of the time and the duration of each activity (one hour) and the group work (MI3, MI4, MI5, and MI6) meant that the students did not get tired and helped them to maintain their attention and interest. This outcome backs up the studies done by several authors [46, 48, 49]. The pupils’ interest is demonstrated in the results of the satisfaction questionnaire, in which the average score for the activities as a whole was 2.55 out of 3. Bearing in mind that attendance to the program was voluntary; another detail that reveals the pupils’ degree of interest is their high rate of attendance (97.1%). Their self-esteem is also visible in the video recordings, with pupils making interesting contributions and demonstrating assurance in their arguments (AI4). Furthermore, taking affective characteristics into account, the design of the activities led to the participating researchers, in addition to facilitating learning, acquiring the role of people of trust, demonstrating support, and creating links, thereby improving the pupils’ self-esteem. This result coincides with those obtained by Moore and Ashcraft [71] and Rice et al. [72]. According to the data collected in the field diary and in the recordings, the rejection and phobia shown by some pupils in the first activity decreased to the point of achieving an atmosphere in which all the pupils felt comfortable enough to express their doubts and difficulties (AI5). This improvement in the students’ self-esteem was reflected in their attitude during the program’s activities. It can be appreciated in the recordings that their participation demonstrated perseverance and responsibility with the aim of obtaining the solution or finishing the activity (AI3) and reassurance when asking questions or making comments regarding different aspects (about mathematics or other issues) of the activities carried out. Their reasoning showed respect for others, evaluating the argument itself rather than the person making it (AI4). The fact that they were at ease with the situation can also be observed in their body language and movements in the different spaces in which the activities were carried out, which, as pointed out by different authors [23, 69], constitutes non-verbal evidence of the students’ emotional state, which is even more revealing than verbal evidence. This atmosphere avoids situations of embarrassment, which are considered to be one of the reasons for which adolescents require the most pedagogical support, as highlighted by Manavella and Martín [73]. In the teaching and learning process, the researchers encouraged communication (mainly oral), which made it possible for pupils to reduce or tone down instances of anxiety or blockage (AI6), to improve their self-confidence (AI5), and to help deepen their conceptual understanding (MI7 and MI8). Those findings support the research on the impact of communication in mathematics done by Fernández-Angulo et al. [74] and Lomibao et al. [40] regarding the effect of communication in mathematics. All of the above is supported by the data extracted from the semi-structured interviews with mathematics teachers and orientation staff, who noted a clear change in the attitude of these students towards mathematics during the course of the program.

Finally, the high degree of mediational and affective suitability of the intervention program is complemented by the results of the assessment record, which show that 83% and 94%, respectively, of the pupils managed to pass the subject of mathematics at the end of the 2017-2018 and 2018-2019 school years. This growing trend in the evolution of academic performance is similar to that obtained with students who are not at risk. Overall, the most notable difference between the students who participated in the program and those who did not can be observed in that in the former, the percentage increase in pass marks between the beginning and the end of the school year is higher (24% compared to 7.5%). These results should be taken with caution, given that not all of the variables influencing academic performance have been studied [75]. Furthermore, the data extracted from the semi-structured interviews of their teachers indicate that a clear effect of the stimulus program on academic results cannot be observed. The number of activities in the program (14 activities of one hour outside of the school timetable) should be considered, as should the difference between the methodology employed in the program and that used in normal classes. However, in the interviews, the mathematics teachers and orientation staff highlighted a visible change in attitude towards mathematics in their classes.

6. Conclusions

The mathematical stimulus program based on STEAM activities has been demonstrated to have a significantly positive effect on the affective dimension of mathematics among pupils at risk of social exclusion due to family reasons. Given the stability of the beliefs and the short duration of the program, they were only analyzed at the beginning in order to be able to guide the teaching and learning process according to the theoretical framework employed. The positive correlation between the pleasure and effort factor and the self-concept factor is key for students of this profile due to difficulties concerning their self-perception. As for the other parts of the affective domain, the programme has shown a high level of affective suitability, which comes from its high level of meditational suitability. This shows that the two factors are strongly interconnected in this area. It provided extra-curricular assistance that was not based on reinforcement via the repetition of contents but rather stimulated interest in learning via the use of a variety of interdisciplinary contents and resources, working with small groups in an atmosphere of trust, which has been crucial in order to make the students feel comfortable. The results show that the activities in which pupils considered that they had learned most were precisely those that they considered to be more difficult and had more original contents. The fact that the researchers were not able to intervene in these students' school mathematics classes makes it impossible to extract conclusions concerning the effects of the intervention program with regard to their academic performance.

As regards the development of the research, it is important to highlight its limitations. First of all, the selection of such a specific sample proves quite complicated as students' pedagogical history is not always available at the beginning of the academic year, thus hindering an increase in the sample size. Secondly, the number of activities in the program, since it is an after-school program, is not very high. Therefore, we believe that to have more lasting results, the number of activities should be increased. These facts limit the scope of the study and will require the expansion of its dimensions in order to discover the aspects upon which future research should be focused and deepened. So, it's important to look at how well the program works with other people. This is related to how well it works with this group's emotions, which can be seen in the recordings of the activities and the semi-structured interviews. All of the above should be considered in light of the Save the Children report [2], which, given the recent global pandemic situation, predicts an increase in the number of students at risk of social exclusion due to their family circumstances.

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