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Higher Normal School of Bou Saada
Department of Mathematics and Laboratory
of Mathematics and Applied Physics

LMAP
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2022

ENS Bou-Saada
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CERTIFICATE OF PARTICIPATION

The Organizing Committee of the First National Conference on Mathematical Analysis and Algebra (30 Novembre 2025) is pleased to award this certificate to : *Bilal Basti* from the,
University Pole of Mohamed Boudiaf - M'sila,
in recognition of his active participation in the conference with an oral presentation entitled:
" Stability Analysis and Implications for Studying Tuberculosis Dynamics in Algeria "
Topic: *Partial Differential Equations and Applications*
Co-author:

THE NATIONAL CONFERENCE ON MATHEMATICAL ANALYSIS AND ALGEBRA
ÉCOLE NORMALE SUPÉRIEURE DE BOUSAADA

الملتقى الوطني حول التحليل الرياضي والجبر
THE NATIONAL CONFERENCE ON MATHEMATICAL ANALYSIS AND ALGEBRA
ECOLE NORMALE SUPERIEURE DE BOU-SAADA

رئيس الملتقى
د.زيان ابراهيم

The First National Conference on Mathematical Analysis and Algebra

THE NATIONAL CONFERENCE ON MATHEMATICAL ANALYSIS AND ALGEBRA
ÉCOLE NORMALE SUPÉRIEURE DE BOUSAADA

November 30, 2025 in Bousaada, Algeria
(1^{St} NCMAA 2025)

The topics interest is:

- Applied Functional Analysis.
- Fuzzy Sets and Applications.
- Partial Differential Equations and Applications.
- Mathematics and Applications.
- Number Theory.

Stability Analysis and Implications for Studying Tuberculosis Dynamics in Algeria

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Abstract

This paper analyzes a fractional SECIR model to study infectious disease dynamics, particularly their impact on individuals with chronic conditions. We establish the existence, uniqueness, and stability of solutions under specific parameter constraints. Using Algerian health data, we estimate model parameters and demonstrate that the basic reproduction number for Tuberculosis in Algeria is below one, suggesting disease control is achievable through vaccination, treatment, and isolation measures.

Keywords: Mathematical modeling; infectious disease; existence; stability; estimation parameters.

Introduction

Our SECIR model divides the population (denoted as N) into five classes: Susceptible S, Exposed E, Chronic diseases C, Infected I, and Recovered R. The parameters of the SECIR model are defined as follows:

∘ Λ is the influx rate that expresses the arrival of people (birth rate and visitors from other societies).

∘ We denote by $\mu \leq \Lambda$ the rate of natural death population.

∘ σ signifies the death rate of infected individuals with chronic conditions, excluding infectious diseases. The inclusion of σ accounts for the higher significance of the death rate among individuals with chronic diseases compared with other compartments.

∘ β_1 and β_2 are the contact rates between the susceptible S and infectious populations C and I.

∘ θ and δ describe the rates of transfer of exposed E to infectious populations C and I respectively.

∘ p and q represent the recovery rates from infectious populations C and I respectively.

∘ κ and γ are the death rates of the populations C and I due to the infectious diseases respectively.

∘ υ is the vaccine rate of the suspected population, and τ is the rate of transfer of recovered population R even those who were vaccinated to the susceptible population S, (taking into account some infectious diseases have various versions, and the vaccine might not always be fully effective due to mutations).

For $0 \leq t \leq T < \infty$, and $0 < \alpha \leq 1$, we have:

$$\begin{cases} {}^{C}\mathcal{D}^{\alpha}_{0+} S(t) &= \Lambda N(t) - \left(\frac{\beta_1 C(t)+\beta_2 I(t)}{N(t)} + \upsilon + \mu\right) S(t) + \tau R(t), \\ {}^{C}\mathcal{D}^{\alpha}_{0+} E(t) &= \frac{\beta_1 C(t)+\beta_2 I(t)}{N(t)} S(t) - (\theta + \delta + \mu) E(t), \\ {}^{C}\mathcal{D}^{\alpha}_{0+} C(t) &= \theta E(t) - (p + \kappa + \sigma + \mu) C(t), \\ {}^{C}\mathcal{D}^{\alpha}_{0+} I(t) &= \delta E(t) - (q + \gamma + \mu) I(t), \\ {}^{C}\mathcal{D}^{\alpha}_{0+} R(t) &= \upsilon S(t) + pC(t) + qI(t) - (\tau + \mu) R(t). \end{cases} \tag{1}$$

Infection transmission alterations within the SECIR model can be interpreted by referring this chart:

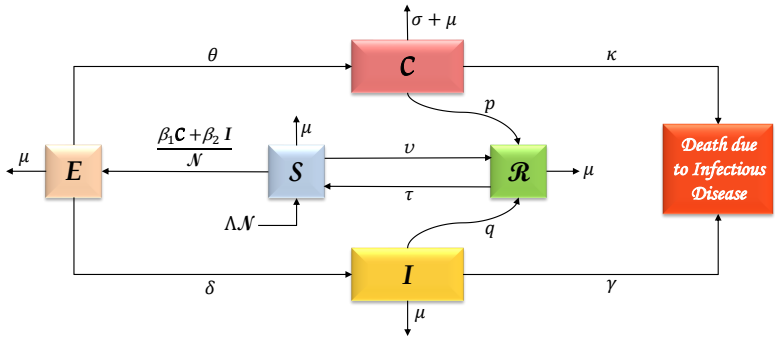

Figure 1: Transmission scheme for the SECIR model of an infectious disease

Analysis for the Fractional SECIR Model

Lemma 1 *Let N_0 be the initial total population at $t = 0$, where $0 \leq t \leq T < \infty$, then the solution of the considered population dynamic model is restricted to the feasible region given by*

$$(S, E, C, I, R) \in \mathbb{R}_+^5, \ S(t) + E(t) + C(t) + I(t) + R(t) = N(t) \leq \mathcal{N} = N_0 \exp\left(\frac{(\Lambda - \mu) T^\alpha}{\Gamma(\alpha + 1)}\right).$$

This shows the boundedness of the population dynamic model under consideration.

Now, we need to normalize the SECIR model (1). Therefore, we put:

$$\mathcal{S}(t) = \tfrac{S(t)}{\mathcal{N}}, \quad \mathcal{E}(t) = \tfrac{E(t)}{\mathcal{N}}, \quad \mathcal{C}(t) = \tfrac{C(t)}{\mathcal{N}}, \quad \mathcal{I}(t) = \tfrac{I(t)}{\mathcal{N}}, \quad \mathcal{R}(t) = \tfrac{R(t)}{\mathcal{N}}, \tag{2}$$

then we obtain

$$\begin{cases} {}^C\mathcal{D}_{0+}^\alpha \mathcal{S}(t) &= \Lambda - (\beta_1 \mathcal{C}(t) + \beta_2 \mathcal{I}(t) + \upsilon + \mu)\mathcal{S}(t) + \tau \mathcal{R}(t), \\ {}^C\mathcal{D}_{0+}^\alpha \mathcal{E}(t) &= (\beta_1 \mathcal{C}(t) + \beta_2 \mathcal{I}(t))\mathcal{S}(t) - (\theta + \delta + \mu)\mathcal{E}(t), \\ {}^C\mathcal{D}_{0+}^\alpha \mathcal{C}(t) &= \theta \mathcal{E}(t) - (p + \kappa + \sigma + \mu)\mathcal{C}(t), \\ {}^C\mathcal{D}_{0+}^\alpha \mathcal{I}(t) &= \delta \mathcal{E}(t) - (q + \gamma + \mu)\mathcal{I}(t), \\ {}^C\mathcal{D}_{0+}^\alpha \mathcal{R}(t) &= \upsilon \mathcal{S}(t) + p\mathcal{C}(t) + q\mathcal{I}(t) - (\tau + \mu)\mathcal{R}(t), \end{cases} \tag{3}$$

along with the positive initial conditions

$$\mathcal{S}(0) = u_1, \quad \mathcal{E}(0) = u_2, \quad \mathcal{C}(0) = u_3, \quad \mathcal{I}(0) = u_4, \quad \mathcal{R}(0) = u_5. \tag{4}$$

Theorem 2 *Let $\alpha \in (0, 1]$ and $\beta_1, \beta_2, p, q, \theta, \delta, \kappa, \gamma, \tau, \upsilon, \sigma, \mu, T \in \mathbb{R}_+$, be such that*

$$\ell = \max\{\beta_1 + \beta_2 + \upsilon, \delta + \theta, p + \kappa + \sigma, q + \gamma, \tau\}.$$

We assume

$$\frac{T^\alpha (\ell + \mu)}{\Gamma(\alpha + 1)} < 1. \tag{5}$$

Hence, there exists a unique solution to problem (3)–(4) on $[0, T]$.

Theorem 3 *The basic reproduction number of system (3) is expressed as*

$$\mathfrak{Rp} = \frac{\Lambda(\tau + \mu)}{\mu(\theta + \delta + \mu)(\tau + \upsilon + \mu)} \left(\frac{\theta \beta_1}{p + \kappa + \sigma + \mu} + \frac{\delta \beta_2}{q + \gamma + \mu}\right). \tag{6}$$

We define the positive real values

$$\begin{aligned} &\lambda_1 = \delta + \theta + \mu, && \lambda_2 = p + \kappa + \sigma + \mu, \\ &\lambda_3 = q + \gamma + \mu, && \eta_1 = \upsilon(\kappa + \sigma) + \mu(\upsilon - p), \\ &\eta_2 = \upsilon\gamma\delta + \mu\delta(\upsilon - q), && \eta_3 = \lambda_1(\lambda_3 - \upsilon) + \lambda_2(\lambda_1 - \upsilon) + \lambda_3(\lambda_2 - \upsilon), \\ &\eta_4 = \frac{\eta_1 \theta}{\lambda_2} + \frac{\eta_2 \delta}{\lambda_3}, && \eta_5 = \mu + \frac{\theta(\kappa + \sigma + \mu)}{\lambda_2} + \frac{\delta(\gamma + \mu)}{\lambda_3}, \end{aligned}$$

to simplify the calculation for getting the following theorem.

Theorem 4 *The system (3) has two types of equilibrium points*

1. *Disease-free equilibrium*

$$\mathfrak{Dfp} = (\mathcal{S}_0, \mathcal{E}_0, \mathcal{C}_0, \mathcal{I}_0, \mathcal{R}_0) = \left(\frac{\Lambda(\tau+\mu)}{\mu\lambda_4}, 0, 0, 0, \frac{\Lambda\upsilon}{\mu\lambda_4} \right).$$

2. *Endemic equilibrium point* $\mathfrak{Eqp} = (\mathcal{S}^*, \mathcal{E}^*, \mathcal{C}^*, \mathcal{I}^*, \mathcal{R}^*)$ *which is*

$$\mathfrak{Eqp} = \left(\frac{\lambda_1}{\lambda_6}, \frac{\lambda_1(\mathfrak{Rp}-1)}{\lambda_5\lambda_6}, \frac{\theta\lambda_1(\mathfrak{Rp}-1)}{\lambda_2\lambda_5\lambda_6}, \frac{\delta\lambda_1(\mathfrak{Rp}-1)}{\lambda_3\lambda_5\lambda_6}, \mathcal{R}^* \right),$$

where

$$\mathcal{R}^* = \mathcal{R}_0 \left(1 - \frac{\lambda_0\lambda_1}{\lambda_5\lambda_6}(\mathfrak{Rp}-1) \right),$$

with

$$\lambda_0 = \frac{\eta_4 + \upsilon\mu}{\Lambda\upsilon}, \qquad \lambda_4 = \tau + \upsilon + \mu,$$
$$\lambda_5 = \frac{\tau\eta_5 + \mu\lambda_1}{\mu\lambda_4}, \qquad \lambda_6 = \frac{\beta_1\theta}{\lambda_2} + \frac{\beta_2\delta}{\lambda_3}.$$

The existence of the endemic equilibrium point is contingent upon $\mathfrak{Rp} > 1$.

Data Fitting Analysis through Numerical Simulation

In this section, we validate our analytical findings by establishing specific parameter values and employing the Adams-type predictor-corrector method [5,6] to achieve a numerical simulation of the proposed nonlinear system (1) to obtain an approximate solution for the proposed model.

This section also provides a focused data analysis of the Tuberculosis pandemic in Algeria to reveal the dynamics and trends of the virus in the country. Utilizing a dataset from authoritative health sources, we employ statistical and graphical methods to scrutinize key epidemiological indicators over specific periods. This study contributes valuable insights into ongoing endeavors aimed at comprehending and addressing the Tuberculosis situation in Algeria (see [1]).

Figure 2 presents a 40-year timeline (1982 onwards) of confirmed Tuberculosis cases, highlighting a noteworthy decline after an initial surge [7]. This decline substantiates the effectiveness of the Algerian government's health interventions for disease control.

The consistent alignment of the predictive model with the observed cumulative infection pattern further reinforces the robustness of the analysis over an extended period.

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[1] B. Basti, B. Chennaf, M. A. Boubekeur, and S. Bounouiga, *Fractional mathematical model for exploring the influence of infectious diseases on population with chronic conditions*, Adv. Theory Simul., **7**(8) (2024), 2301285. DOI: 10.1002/adts.202301285

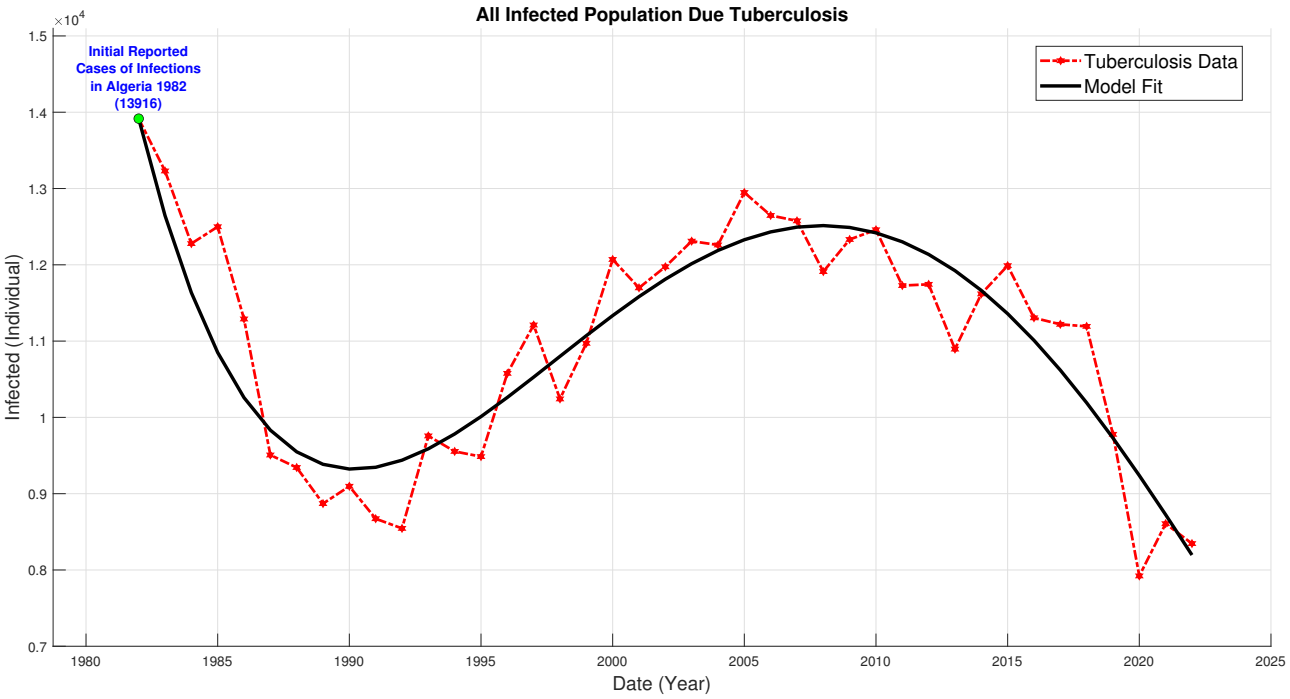

Figure 2: Real cases reported of Tuberculosis in Algeria (represented by red) from 1982 to 2022 and the best-fit curve from the proposed model (shown by black line) for $\alpha = 1$.

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THE NATIONAL CONFERENCE ON MATHEMATICAL ANALYSIS AND ALGEBRA

ÉCOLE NORMALE SUPÉRIEURE DE BOUSAADA

The First National Conference on Mathematical Analysis and Algebra

November 30, 2025 | Bousaada, Algeria (1^{St} NCMAA 2025)

Conference Program

General Schedule

Time	Activity
08:30–09:00	**Registration of Participants**
09:00–09:30	**Opening Ceremony**
09:30–10:00	First Plenary Lecture (**Prof. Abdelaziz Amroune**) University of Msila | Soixante ans d'ensembles flous, une mathématique en développement **(Chairperson: Prof. Belouadah Hocine)**
10:00–10:30	Second Plenary Lecture (**Prof. Ahmed Ait Mokhtar**) ENS Kouba | Suites récurrentes linéaires, tressages et application en cryptographie **(Chairperson: Prof. Belouadah Hocine)**
10:30–11:00	Third Plenary Lecture (**Dr. Mohamed Boudiaf**) ENS Kouba | المنطق الضبابي كإطار رياضياتي لتوسيع حدود المنطق الكلاسيكي وتمثيل الغموض **(Chairperson: Prof. Belouadah Hocine)**
11:00–11:10	كلمة السيد رئيس الجمعية الجزائرية للرياضيات الصناعية و التطبيقية **(Prof. Benhamidouche Noureddine)**
11:10–11:30	**Group Photo and Coffee Break**
11:30–13:30	**Parallel Technical Sessions**
13:30–14:00	**Closing Ceremony and Awards**
14:00	**End of Conference**

Parallel Technical Sessions (11:30–13:40)

Session 1: Fuzzy Sets and Applications

(Chairperson: Dr. Bouad Aissa, Room S19)

Time	Author	Title	Affiliation
11:30–11:45	Hassane Bouermel	Ordered Relations and Non-Associative Structures	University Center of Barika
11:45–12:00	Neche Noureddine	A Study of Neutrosophic Sets	University of Msila
12:00–12:15	Harzelli Mohamed Rafik	Classification of Groups of Order 12	University of M'sila
12:15–12:30	Hadjer Berri	Several Properties of Fuzzy Topological spaces in Šostak's sense	University Center of Barika
12:30–12:45	Abdelghani Derardja	The Complete Lattice Structure of Fixed Points for L-Fuzzy Monotone Multifunctions	University of Batna 1
12:45–13:00	Mohamed Saad	Fuzzy subfield	University of M'sila
13:00–13:15	Bouad Aissa	Compatibility and Traces of Bipolar Fuzzy Relations: Characterizations and Extensions	University of M'sila
13:15–13:30	Brahim ziane	A Study on Fuzzy Semigroups and Their Algebraic Properties	ENS Bousaada

Session 2: Applied Functional Analysis

(Chairperson: Prof. Elhadj Dahia, Room Amphi2)

Time	Author	Title	Affiliation
11:30–11:40	Bochra Zeghad	Efficient extragradient method for pseudomonotone equilibrium problems in Hilbert spaces	Ferhat Abbas University Setif-1
11:40–11:50	Naceur Chegloufa	A Study on Neutral -Hilfer Fractional Evolution Equations with Delay	Saad Dahlab University
11:50–12:00	Hassan Zine	A Study of Nearest Points in Linear Spaces with Asymmetric Norms	Mouloud Mammeri University of Tizi-Ouzou
12:00–12:10	Faiz Latreche	Banach-Steinhaus theorem for bilinear mappings between topological vector spaces	ENS of Bousaada
12:10–12:20	Nassim Ferahtia	Some properties of certain functional spaces	University of M'sila
12:20–12:30	Abdellatif Smati	From Normality to n-Normality: Extensions and Limitations in Operator Theory	ENS of Bousaada
12:30–12:40	Nasreddine Lakel	Stabilizing Control of Quadrotor Drones	University of M'sila
12:40–12:50	Tahar Brahimi	Response Spectra Using ARMA Model	Ecole Normale Supérieure de Laghouat
12:50–13:00	Zouheyr Zeghad	Boundedness of sublinear operators on two weighted Herz spaces with variable exponents	Ecole Normale Supérieure de Bousaada

Session 3: Number Theory

(Chairperson: Dr. Meselem Karras, Room S20)

Time	Author	Title	Affiliation
11:30–11:45	Salim Badidja	Some Results Involving Combinatoric Identities of Certain Particular Linear Recurrent Sequences	Kasdi Merbah University, Ouargla
11:45–12:00	Chellal Redha	An explicit formula for generalized Euler polynomials	USTHB
12:00–12:15	Dyhia FEDALA	On the Diophantine equation $(a^k-1)(b^l-1)=c^m-1$	USTHB
12:15–12:30	Yahia Zouareg	On a diophantine equation arising from Lehmer conjecture	National Higher School for Hydraulics, Blida
12:30–12:45	Oualid Djouabi	Generalized bivariate Fibonacci quaternions	Kasdy Merbah University, Ouargla
12:45–13:00	Amina Bellil	Quasi-twisted codes over R	USTHB
13:00–13:15	Mohammed Mekkaoui	On the a-points of some Dirichlet L-functions	Department of Mathematics, École Normale Supérieure, Kouba, Algiers, Algeria
13:15–13:30	Meselem Karras	Somme hyperbolique bidimensionnelle avec condition de PGCD	University of Tissemsilt

Session 4: Partial Differential Equations and Applications

(Chairperson: Dr. Abdelhamid Tallab, Room Amphi1)

Time	Author	Title	Affiliation
11:00–11:10	Beroudj Mohammed Elamine	Solution of a Linear PDE via Spectral Analysis	Department of Mathematics, University of Batna 2, Fesdis - Batna
11:10–11:20	Bouyelli Antar	The Extended Spectrum in the Framework of Generalized Invertibili	Department of Mathematics, University of Batna 2, Fesdis - Batna
11:20–11:30	Haithem Benharzallah	Approximation for Fredholm integro-differential equations	Department of Mathematics, University of Batna 2, Fesdis - Batna
11:30–11:40	Bilal Basti	Stability Analysis and Implications for Studying Tuberculosis Dynamics in Algeria	University Pole of Mohamed Boudiaf - M'sila
11:40–11:50	K Chadi	A Mathematical Study of Quasistatic Contact Problems Involving Time-Fractional Derivatives	University of M'sila / University of Sétif 1
11:50–12:00	Noureddine Dechoucha	Nonlinear Elliptic Equation with Variable Exponents	Department of Mathematics
12:00–12:10	Oussama Khaldi	Exponential Growth and Blow-Up Time Estimates for a Viscoelastic Wave Equation with Variable Exponent	University of Laghouat
12:10–12:20	Rabah Djemiat	Radially Symmetric and Traveling Waves for Nonlinear PDEs	Higher National School of Hydraulics, Blida
12:20–12:30	Soufiane Benkouider	Local existence and blow up of solutions for a logarithmic nonlinear viscoelastic wave equation with time-varying delay	University of Laghouat
12:30–12:40	Haimed Amina	Solving Nonlinear Volterra Integral Equations by the Newton-Kantorovich Method Combined with the Composite Repeated Trapezoidal Rule	Mohamed Boudiaf University of M'sila
12:40–12:50	Safa Bachir	Existence and multiplicity of solutions for fractional problems	University of M'sila

Time	Author	Title	Affiliation
12:50–13:00	Bessadat Maymouna	Analytical study of a fractional differential system of type BEAM with integral conditions	ENS Boussaada
13:00–13:10	Ait Mohammed Hicham	On Existence, Uniqueness and Stability of Solutions to Caputo Fractional Variable Order -IVPs under MultiPoint Boundary Conditions	Applied Mathematics Laboratory, Kasdi Merbah University, BP511, Ouargla, 30000, Algeria.
13:10–13:15	Toufik Heraiz	On the Existence and Uniqueness of one Dimensional inverse problem for fractional wave equation with Overdetermination Condition	University of M'sila

Session 5: Mathematics and Applications

(Chairperson: Dr. Abbassi Ahmed, Room Amphi3)

Time	Author	Title	Affiliation
11:30–11:40	Abdelhamid Rehouma	Orthogonal polynomials of the second kind and their utilizations	University of Eloued
11:40–11:50	Abdelhak Omar	On the conjecture of double Roman domination edge-critical graphs	University of Blida 1
11:50–12:00	Hanaa Belkacem	A Historical and Analytical Study of Amicable Numbers	ENSSI Algiers
12:00–12:10	Messaoud Taleb Hacine	Applications of Algebra in Solving Topological Problems (Brouwer Fixed Point Theorem)	ENS Boussaada
12:10–12:20	Taleb Bahmed Amal	The impact of using AI in learning mathematics	ENS Boussaada
12:20–12:30	إسماعيل قدي	الكسور في الحضارة العربية الإسلامية - مقارنة بين التقليدين الرياضيين بالمشرق والغرب الإسلاميين	المدرسة الوطنية العليا للعلوم الإسلامية - دار القرآن - جامع الجزائر
12:30–12:40	موسى وعلي إبراهيم	ملامح تعليمية من خلال عرض تحليلي لمخطوط "البهجة السّنية في مبدأ العلوم الرياضية" لأحمد بن يوسف الأزهري - الشهير بالطّباخ	المدرسة الوطنية العليا للعلوم الإسلامية - دار القرآن - جامع الجزائر
12:40–12:50	لبصير ياسين	الهندسات المتعددة ودورها في تعميق القيم الفلسفي والعرفي للطالب الجامع	المدرسة العليا للأساتذة بوسعادة
12:50–13:00	حمزة لخشين	منهج الخوارزمي و عمر الخيام في حل المعادلات: دراسة مقارنة في تطور الفكر العربي الاسلامي	المدرسة الوطنية العليا للعلوم الإسلامية - دار القرآن - جامع الجزائر
13:00–13:10	خليصة حططاش	معالجة تحليلية لبعض نصوص الخوارزمي الجبرية	المدرسة الوطنية العليا للعلوم الإسلامية - دار القرآن - جامع الجزائر

Time	Author	Title	Affiliation
13:10–13:20	مقتدر زروقي	نظم أبي إسحاق التلمساني ت 697 ه 1298 / في الجبر معادلات الد1° والد2° نموذجا	المدرسة الوطنية العليا للعلوم الإسلامية - دار القرآن - جامع الجزائر
13:20–13:30	حجاب شيماء	تطبيقات الرياضيات في الملاحة البحرية في المحيط الهندي: دراسة مقارنة في أعمال ابن ماجد وسليمان المهري	المدرسة الوطنية العليا للعلوم الإسلامية - دار القرآن - جامع الجزائر
13:30–13:40	Abbassi Ahmed	Le concept de droite en algèbre linéaire etude didactique	ENS Bousaada