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STUDY OF WORK TEAMS ACTIVITY BY ASYMMETRICAL PULSES MODEL

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This article presents the use of the asymmetric pulses model written under the binomial form $(a + b\tau)^n$, n being the number of the system's constituents with $a \neq b$ some parameters of a certain medium, for studying the opportunity and correctness of modernizing some working methods in engineering education. Considering the future employment of students in different organizations, the model tests the efficiency of the project-based work in student teams in all activities, taking into account the characteristics of the team and any changes that may have occurred along the way.

Keywords: asymmetrical pulses, dynamic system, work team, quality management, project-based evaluation

1. Introduction

Inside a company, the speed of work is crucial in order to correct any mistake from the very beginning [1], therefore it is obvious to underline the role of the organization, the importance of on-site changes during the work and the maximum speed of all the actions [2]. In context, the concept of "work team" is addressing the classical model of a team: *forming, storming, norming and performing.* Adding the "*adjourning"* concept, it results that work in an efficient team ask several developments and adaptive methods [3].

Mathematical models capable of describing complex system behaviour, increasing role of AI-driven biomedical prediction tools are reshaping research and innovation in the life sciences and engineering [4,5,6].

This is the reason that in the modern engineering teaching system we want to use new and more interactive methods [7, 8] that we certify and analyse here in details with the help of a mathematical model proposed by us [9].

In pre-university education, working with projects in teams for obtaining a mark is already successfully implemented [4]. As a proven technique, in case of examinations at university level, we propose that the students receive a theme and a set of suggestions in STEM domains (Sciences, Technics, Engineering,

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Mathematics) for solving the problem. So creative capabilities can be evidenced directly or within a local area network or in a wireless connection. The answer could be individual or collective. If collective, the answer must be approved or rejected, and the process continues.

A mathematics-based model for improving ***the quality*** of the work in this way is presented in the paper. We want to apply this strategy at the Faculty of Applied Science (FSA), Faculty of Entrepreneurship, Business, Engineering and Management (FAIMA), and The Faculty of Industrial Engineering and Robotics (IIR) from National University of Science and Technology "Politehnica" Bucharest (UNSTPB), as we stated in [9].

At FSA and FAIMA, laboratory activities are already conducted in groups composed of three students, size chosen to ensure the active participation. The results obtained through collaborative work within a *coordinated team*, as opposed to individual engagement, clearly indicate that collective endeavour yields demonstrably superior outcomes.

This observation suggested us the main ideas of this paper: *a structured form of collaboration* could likewise prove advantageous in examination contexts, potentially fostering deeper analytical engagement and may facilitate the development of substantive *project-based outputs* with prospective applicability.

Other faculties within UNSTPB—for example, the Industrial Management course delivered in English at the FIIR—employ a *project-based* method of evaluation, allocating two hours per week to project work and 40 points in the final examination [7]. Students do not carry out practical laboratory activities but instead attend a one-hour tutorial each week, with the curriculum centred on additive *manufacturing and quality management* to prepare them for future roles in industry. This project-based model is relevant to the present discussion because it demonstrates that an alternative form of assessment is already successfully applied.

2. Method and discussions

1. **Basic considerations**. We propose *new methods* aligned with the future professional activities of the graduates. Students receive a project topic related to a subject studied and are required to work together and propose a *general solution*, submitting their work *individually* and specifying the *mathematical and physical methods* employed. Papers that meet the requirements are graded, while students who do not pass will be required to retake the examination.

The effectiveness of this project-based method is analysed in the paper using the asymmetric pulse model, which enables a *mathematical representation of variations in student performance* and the influence of external factors. This model is particularly suitable since the asymmetry reflects that participants are not identical, unforeseen and influences may arise throughout the process, allowing us to evaluate how consistently the new method supports learning outcomes.

This scenario was inspired by numerous phenomena in Physics that display pulse-like interactions. For example, when a phenomenon emerges abruptly within a confined space-time interval, its long-distance propagation experiences distortion effects which alter the original pulse, a process that in our educational analogy corresponds to the variability in student performance caused by external factors. Many concepts used in physics have similar meaning in economy. For example, the "configuration" concept in economic engineering means a complete set of the functional and physical characteristics of an entity (a product) [2]. In Lagrange formalism in Physics the "configuration" represents the complete set of convenient data that uniquely define the system [10], a "point" in the abstract n *−dimensional space of configurations*, inside which the evolution of the system is studied. As it was proposed in the frame of a large participation projects, namely "Using Physics methods for problems' solving in engineering by computer help"and"Teaching Physics by technical applications" - initiated by M. A. Ghelmez (Dumitru) [11], the basic idea is to link each-others STEM domains for more efficient activity. Such analogies support our proposed evaluation model, as the configuration concept illustrates that both physical and economic systems can be described by a set of defining parameters, suggesting that student performance can likewise be modelled using a structured set of variables.

Starting from such practical reasons, we consider realistic our mathematical model, based on the combinatorial analysis, frequently used for treating some old problems in a new manner [12], consisting in a general expression, $(a + b\tau)^n$, $a \neq b$, and we present the main features connected with the number n of the constituents and the interaction between them. We exemplify by using ***different numbers n*** of constituents, in connection with practical situations [12]. The delay operator τ captures differences in timing of individual contributions, the effective temporal offset between successive student contributions, capturing variations in learning, pace, communication efficiency, and the time required for individual cognitive processing. The coefficients a and b characterise the relative influence of immediate, well-structured inputs and delayed, feedback-driven responses, thereby modelling the heterogeneous performance patterns typically encountered in collaborative student groups. A normalisation condition $a + b = 1$ ensures conservation of the overall informational contribution of the team, irrespective of internal redistribution. An asymmetry parameter $\delta = (b - a)/2$ provides a direct quantification of the imbalance between efficient and delayed components.

2. **Model description**. Consider a finite set of n individuals acting together. Each individual is influenced by a delay operator τ, which represents the time required for information to be transmitted from one to another, in a limited time total interval. In electronics, the delay time is well defined, but it is not specified

whether it follows a special statistical distribution. The information transmitted within the medium can be represented by a polynomial expression with $k+1$ terms:

$$S=(1+\tau)^n S_i = (C_n^0\ \tau^0 + C_n^1\ \tau^1 + \cdots + C_n^k\ \tau^k + \cdots + C_n^n \tau^n)^n S_i \tag{1}$$

$$S=\sum_{k=0}^{n} C_n^k\ \tau^k\ , \qquad t_0=0\ ,\ S_i=1,\ k\ \in[0,1] \tag{2}$$

where the general term τ^k assumes the application of the delay operator k times, and the binomial coefficient C_n^k expresses the theoretical number of possible ways in which information may reach k individuals even though not all these possibilities are realised in practice.

The information (signal) is transmitted so as in every point n of the medium it comes from all the previous $n-1$ points at the moment $t=n\tau$. If $t=1$, allowing for a normalized time axis, it results $\tau=1/n$. This facilitates comparison between different n by ensuring that the total propagation time remains constant across simulations. Therefore, coefficients C_n^k may be interpreted as *theoretical amplitudes* of the information propagation process at the moment $t\ =\ k\tau$. The sum of all binomial coefficients C_n^k - actually all the unordered subsets, is 2^n, and the maximum amplitude occurs at $k=\frac{n}{2}$. Thus, the coefficient

$$\binom{n}{k}=\frac{n!}{k!(n-k)!}=C_n^k \qquad C_n^0=C_n^n=C_0^0=1 \tag{3}$$

has its maximum amplitude when half of the individuals received the information.

The specific form of the signal (pulsed or continuous) is not imposed by the model, but only the combinatorial structure of its propagation.

The binomial form of the operator τ (initiated by C. Toma) implies that the propagation of information follows a mathematical structure in a Newton binomial type development:

$$(x+a)^n=\sum_{k=0}^{n}\binom{n}{k}x^k a^{n-k} \tag{4}$$

A graphical representation of these amplitudes in MATLAB produces a pulse-shaped curve, with a maximum at $k=\frac{n}{2}$. X-axis represents time and Y-axis represents the amplitudes $S_k=C_n^k$. For large values of n, the distribution becomes nearly *continuous* over a limited interval t [13] (analogous to a sinusoidal function or a wave packet), which allows the use of the first and second derivatives in our analysis. MATLAB enables the simulation of the pulse behaviour under different parameter choices and the rapid comparison between theoretical expectations and the numerical structure of the model.

In this case, it is not necessary for information to be transmitted to all n individuals for the entire group to become informed; it is sufficient for approximately half of them to receive it, since the combinatorial structure allows full propagation through subsequent interactions. As n increases, the pulse becomes narrower. A symmetric pulse corresponds to the case $a = b = 1$ in the general binomial development $(a + b\tau)^n$ and the asymmetric one $a \neq b$, with $a + b = 1$.

Therefore, if we apply to a team of n individuals and assume that information is transmitted through the binomial mechanism within the total time $t = n\tau$, half of the individuals, namely $\frac{n}{2}$, receive the information within this interval, while the remaining $\frac{n}{2}$ receive it in an additional similar interval.

The model has important general and advantageous features: it can be extended to describe a continuous material medium and can be applied to a signal propagating throughout the entire medium, from one group to another, according to the combinatorial structure C_n^k, not to a signal that propagates along a single direction, step by step (by *contiguity).* It may be tested against any real phenomenon by introducing a concrete physical quantity (electric, optical, or thermal signal, pulsed or continuous) [14].

Within this framework, the *ergodic hypothesis* from Statistical Physics [15] provides an additional conceptual foundation for interpreting the pulse as a representative descriptor of the system's global behaviour. A system is considered ergodic if, for almost any initial condition, the temporal average of an observable coincides with its ensemble average:

$$\bar{f} = \langle f \rangle \tag{5}$$

where
$$\bar{f} = \lim_{T \to \infty} \frac{1}{T} \int_0^T f\big(x(t)\big)\, dt \tag{6}$$

$$\langle f \rangle = \int_\Gamma f(x)\, \rho(x)\, dx \tag{7}$$

are the temporal average of a physical observable f, and the ensemble average, respectively. $x(t)$ is the state of the system at time t and the integration is performed over the entire phase space Γ and weighted by the probability density $\rho(x)$. By assuming that the system explores a sufficiently large portion of its accessible states during the propagation process, this hypothesis supports the equivalence between the *ensemble of all combinatorial configurations* and the *time evolution* of the pulse, for a long-time evolution.

The ergodic assumption becomes relevant for analysing pulse asymmetry. When the parameters a and b differ, *the distribution no longer remains centred at* $k = \frac{n}{2}$, and the system spends unequal "statistical time" in the left and right regions of the pulse, quantified through the asymmetry factor δ.The shift in the pulse maximum and the distortion of the amplitude distribution can be interpreted as changes in the relative occupation of the system's accessible states [16].

These considerations also inform the estimation of model parameters. In practice, the asymmetry of the pulse provides a sensitive *indicator of how the medium influences the transmission process*, and the ergodic interpretation ensures that these indicators reflect stable, system-wide properties rather than transient fluctuations. Consequently, the combinatorial modelling, asymmetry analysis, and ergodic reasoning offers a coherent framework for our purposes.

In previous work, the *symmetrical* pulse model was used to analyse the situation of an increased on the way working team [9]. A graphical method for determining certain parameters of the model, based on the tangent line at the inflection points [13] of the graph, is presented in Figure 1. The amplitude at the inflection points k_1 and k_2 is denoted by F, the distance between them by D. From the auxiliary triangle it follows that $m = F/(D/2)$ and

$$H = 3F \qquad \text{with } D = k_2 - k_1 \tag{8}$$

since the tangent at the first inflection point intersects the vertical line through the second inflection point at the height:

$$H = F + mD, \qquad m = \frac{H-F}{D} \tag{9}$$

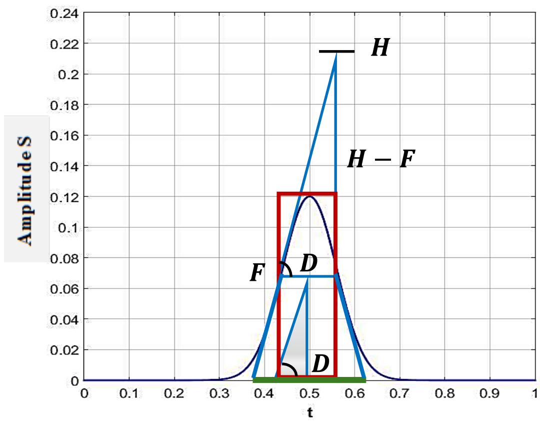

Fig. 1. Amplitude S (divided by 2^n) of discrete pulses versus time normalized to $t = 1$.

These considerations are applied within this paper by using asymmetrical pulses, which provide a good extension in practical problems for modelling pulses when their time length varies when passing through a medium and their symmetrical pattern of pulse amplitudes along the time axis is altered.

3. Results

1. **Asymmetry evidenced by amplitude derivative.** Asymmetrical binomial pulse is analysed in figure 2, by ***amplitude derivative*** graph for $n = 49$ and 36 ($a = 0.3$, $b = 0.7$). These plots highlight the asymmetry in the slope of the pulse at the inflection points. The ratio of time derivatives in the left/right inflection points slightly increases from 1.08 for n=49 to 1.1 for n=36. It results from these graphs that the derivatives at inflection points reveal a *deviation from symmetric*

behaviour, particularly for lower values of n, supporting the model's applicability to different student's groups [8] and validates the model's sensitivity to asymmetry.
2. **Asymmetry evidenced by δ**. It is emphasized [8] that in case of asymmetrical

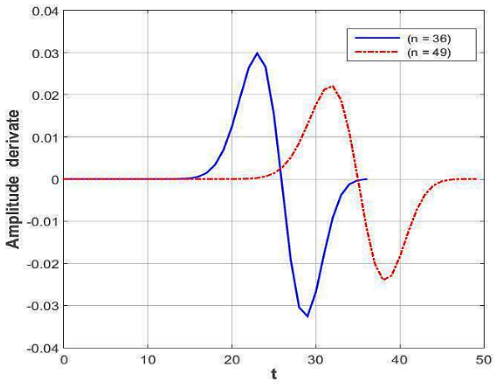

Fig. 2 Time derivative of amplitude for $n = 36$, and $n = 49$, $a = 0.3$, $b = 0.7$

pulses obtained using a combinatorial model, H is no more equal to 3 F , therefore a certain difference denoted as "*Diff*" is added. A small variation δ is used to study the influence of asymmetry from the symmetric form:

$$\delta = (b - a)/2 \tag{10}$$

$$a = \frac{1}{2} - \delta, b = \frac{1}{2} + \delta \tag{11}$$

The differences *Diff* for $n = 10$ $(Diff1)$, $n = 30$ $(Diff2)$, and $n = 100$ $(Diff3)$, $\delta = 0.05 - 0.30$ are summarized in Table 1. When $\delta = 0$, the pulse remains symmetric. As δ departs from zero, the balance between these components shifts, producing a measurable asymmetry in the temporal evolution of the pulse. This parameter therefore quantifies how the medium or transmission process preferentially amplifies or delays specific components of the signal.

Figure 3 couples' different combinations of values for the number n of environmental constituents for all possible values of δ between its maximum and minimum and is provided by TableCurve3D program, useful for giving a complete information about the complex dependence between the different parameters involved in a specific study, so as unknown values can be forecast.
The associated dependence:

$$z = d + e\mathrm{x} + f\mathrm{x}^2 + g \ln \mathrm{y} \tag{12}$$

combines a quadratic dependence on x with a logarithmic dependence on y. The fitted coefficients $d = 0.32013459$, $e = -1.0161138$, $f = 3.8703059$ and $g = 0.103940$, indicate a pronounced nonlinearity in x and smaller contribution from y. The model shows excellent agreement with the data ($r^2 = 0.9991$, adjusted $r^2 = 0.9957$), with a low standard error (0.00499) and a high F-statistic (769.94), confirming its statistical robustness and accuracy.

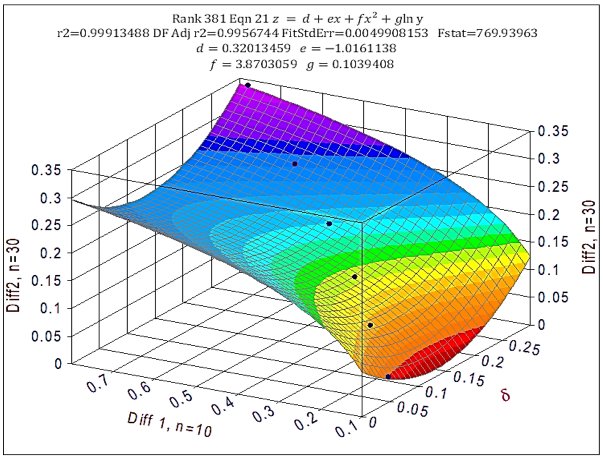

Fig. 3. Fitted surface showing how the model output varies with the number of environmental constituents n and the full range of δ.

Using the wide range of curve-fitting options, the dataset can be fitted to various models, if the type of propagating signal is known. This information supports the interpretation of the response surface by specifying the range within which *Diff2* is expected to fluctuate under the conditions examined. One can see that *Diff* between the approximate values and the real ones is decreasing for δ small and n great and has a maximum for the maximum δ and minimum of *n.* The same conclusion for $n = 100$, as one can see from Table 1.

Table 1

$\boldsymbol{\delta}$	**Diff1** $(\boldsymbol{n = 10})$	**Diff2** $(\boldsymbol{n = 30})$	**Diff3** $(\boldsymbol{n = 100})$
0.05	0.11	0.045	0.02
0.10	0.22	0.095	0.04
0.15	0.32	0.140	0.07
0.20	0.45	0.190	0.08
0.25	0.60	0.250	0.12
0.30	0.78	0.340	0.15

3. **Application.** This previous detailed analysis of the model enables us to use it for our study. Let's consider the constituents $n = 50$ from a work team composed by the students performing the required project in the frame of their final or partial examination. If some students cannot obtain a satisfactory mark, they remain to try again to solve a new project. We are interested to see if the *decreasing of* n leads to a reduction of the quality of the work performed by the remaining team. The total number of combination Z (the sum of all amplitudes) $-$a global quantity for the entire pulse $-$ before and after a reduction in team size, is

$$Z(n) = \sum_{k=0}^{n} C_n^k = 2^n \qquad \text{and} \qquad 2^{n_i} > 2^{n_f} \tag{13}$$

Considering $C_n^k = f(k)$ and the recurrence formula

$$f(k-1) = \frac{k}{(\mathrm{n-k+1})} \cdot f(k) \tag{14}$$

it results for the inflections points:

$$k_{1,2} = \frac{n}{2} \pm \frac{\sqrt{n+2}}{2} = k_{max} \pm \frac{\sqrt{n+2}}{2} \tag{15}$$

where $\sqrt{n+2} \approx \sqrt{n}$ for high n and

$$Max\ f(k) \approx \frac{n!}{\left(\frac{n}{2}\right)!\left(\frac{n}{2}\right)!} = \sqrt{\frac{2}{\pi}} \cdot \frac{1}{\sqrt{n}} \cdot 2^n \tag{16}$$

Therefore, the interval Δk_{max} around k_{max} between the two inflection points is

$$\Delta k_{max} = \sqrt{n+2} \approx \sqrt{n} \tag{17}$$

when n is a great number (for example 50). When calculating the area

$$\Delta k_{max} \cdot Max_{f(k)} = \sqrt{\frac{2}{\pi}} \cdot 2^n \tag{18}$$

formed around the middle of the interval $(0, n)$, the significant values of amplitudes are concentrated within the normalized interval $(50/2 \pm 52)/50$ on the Ox axis. Therefore, 80% of the sum of amplitudes $f(k)$ is concentrated within this area. If n decreases, the width of the rectangle increases, since the ratio $\sqrt{n}/n$ increases, this being a measure of the asymmetry. After a time, the members will join in teams consisting in half of total number (maximum). If the individuals join in larger groups, the number of possible combinations decreases. If the remaining team is grouped in small teams, the number of possible combinations increases that maintains the quality of the work [17,18] of discrete pulses, two representative

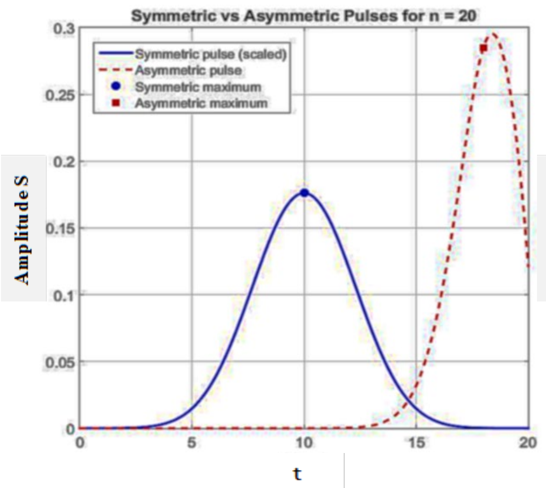

Fig.4. Concentration of amplitude S (divided by 2^n) versus time for the binomial delay operator with $n = 20$.

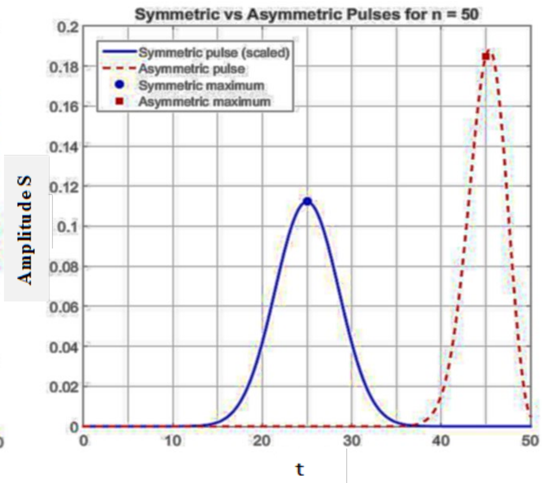

Fig.5. Concentration of amplitude S (divided by 2^n) versus time for the binomial delay operator with $n = 50$.

cases of work teams were examined, corresponding to $n = 50$ - initial work team and $n = 20$ −the remaining team after the examination (Figures 4 and 5). For each value of n, both the symmetric and asymmetric formulations of the binomial expansion were evaluated. The symmetric pulse $a = b = 0.5$ exhibits a maximum located near the midpoint of the temporal interval, around $t \approx 10$ for $n = 20$ and $t \approx 25$ for $n = 50$. The asymmetric pulse generated using $a = 0.1$ and $b = 0.9$, displays a *shift* of the maximum towards the upper end of the interval, with peak values occurring at $t \approx 18$ for $n = 20$ and $t \approx 45$ for $n = 50$, as the previous analysis stated. The graphical comparison of the two pulse types, obtained through spline interpolation to ensure smooth continuous representations, highlights the effect of the coefficients a and b on both the localization and the shape of the resulting maxima, including the shift in peak amplitude and the modification of pulse symmetry. Moreover, it shows that the decrease in the number of participants do not disturb the work since the maximum shift represents the same fraction of n for total number of participants. To complement the theoretical analysis, we conducted a simulation reflecting typical patterns of student performance in laboratory and project-based work. The comparison between symmetric $(a = b = 0.5)$ and asymmetric $(a = 0.1,\ b = 0.9)$ pulses shows that the asymmetric model better captures delayed responses and uneven contributions. Although real data cannot be disclosed for GDPR (General Data Protection Regulation) reasons, the simulated dataset preserves the statistical structure observed in practice, confirming the model's relevance. These observations are consistent with the broader behaviour of the model described earlier in the paper, particularly the dependence of the *Diff* parameter on δ and n, which shows that asymmetry becomes more pronounced for larger δ while remaining weakly sensitive to variations in n. Moreover, the concentration of amplitudes within the central region of the pulse, corresponding to the rectangle that aggregates the dominant contributions, remains preserved across symmetric/asymmetric cases.

This stability indicates that moderate changes in team size or interaction conditions do not significantly impair the effective circulation of information through the medium. Consequently, the cooperative dynamics required to obtain a good result are maintained, supporting the conclusion that the proposed project-based examination method is robust and can be confidently implemented in future partial or final examinations at UNSTPB faculties.

Future work will incorporate student feedback, since negative feedback—where the output is reinjected at the input with opposite sign—has a corrective effect, stabilising the system but slowing its response to external signals. On the other hand, positive feedback reduces delay time but may render the system unstable [19], producing oscillations if the amplification becomes too large $(A \rightarrow \infty)$. Nevertheless, this behaviour mirrors human reactions and influences the final results of cooperative work.

4. Conclusions

Starting from the proven efficiency of project-based teamwork in pre-university education, this study has examined the asymmetric pulse model as a quantitative framework for introducing a new method of student assessment. It is aligned with current efforts to modernise evaluation practices in accordance with professional requirements. Teamwork, exchange of viewpoints, solution development and outcome verification remain essential components of Quality Management and student groups formed for examination purposes are therefore regarded as work teams, applying the concept of *competency.*

The pulses model, inspired by *signal-propagation phenomena* in physics and real life, proposes a way to describe the *interaction* between a signal and the medium, through a *binomial expansion*. In general, the environment is not an empty place, but a structure, acting upon the signal, in constructive or destructive manner.

A certain amount of time is required for this process, corresponding to the delay time τ. The asymmetric version of the model $(a + b\tau)^n$ with $a \neq b$ some parameters of a certain medium composed by n constituents, has been chosen because the n constituents are not identical and many unexpected events may occur during the process. The coefficients a and b characterise the relative influence of immediate, well-structured inputs and delayed. The incorporation of the ergodic hypothesis strengthens the interpretation of the model.

The asymmetry parameter δ, together with graphical methods based on inflection points and the measure *Diff*, captures the imbalance between delayed and non-delayed components. The behaviour of *Diff* across different values of n and δ, supported by TableCurve3D surface fits, shows that asymmetry increases with δ and decreases with n, while the overall pulse structure remains stable. This behaviour is consistent with the ergodic interpretation indicating that the resulting statistical distributions reflect long-term, system-wide behaviour rather than transient fluctuations, and is further validated by derivative-based analysis.

From an educational perspective, the findings indicate that reducing the number of team members does not materially diminish the quality of the collective output, as the combinatorial structure preserves the essential dynamics of information propagation. This supports the use of flexible, project-based evaluation methods and a better structured curriculum in academic environments. The integration of AI-based platforms such as MATLAB and Moodle further enhances the applicability of the model by enabling rapid simulation, optimisation and structured feedback [19].

The study contributes both to the theoretical understanding of asymmetric pulse behaviour and to the development of a pedagogical tool capable of improving collaborative performance and supporting fair assessment. It is our intention to extend the model to additional educational contexts, enhancing its applicability as a quantitative framework for evaluating teamwork, adaptability and competency in STEM-based programmes [20].

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