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ARTÍCULOS

Percepciones del profesorado de música sobre un nuevo software para la evaluación de la entonación en instrumentos musicales

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ES **Resumen:** La entonación es una habilidad imprescindible en el aprendizaje de instrumentos musicales, sobre todo, en los de entonación variable, como los de viento-metal y cuerda frotada. Un problema frecuente es que el alumnado principiante encuentra muchas dificultades de entonación en estos instrumentos durante su aprendizaje. Por ello, dedica una gran cantidad de tiempo a su práctica, al igual que el profesorado en la corrección de los errores relacionados. Este estudio de valoración es parte de uno de más largo alcance que ha diseñado e implementado el software Plectrus para evaluar a tiempo real la entonación en el aprendizaje de instrumentos de cuerda frotada y de viento metal. Para conocer si este software daba respuesta a las necesidades educativas detectadas, se ha realizado un estudio de evaluación estadístico basado en cuestionario que fue cumplimentado por profesorado de escuelas de música y conservatorios de España y Chile (n=41). El cuestionario incluyó tres dimensiones de evaluación (técnica, educativa y global). Una dimensión sobre uso de tecnología digital educativa, así como experiencia profesional, género, edad y formación profesional actuaron como covariables para analizar la influencia en las dimensiones de evaluación. Los resultados cuantitativos fueron triangulados con datos cualitativos recogidos en dos grupos focales (n=10) con el fin de dotar de credibilidad a la interpretación de los resultados. Los resultados indican que Plectrus ha sido evaluado de manera muy positiva por el profesorado en las tres dimensiones de evaluación; se han producido correlaciones positivas entre las tres dimensiones, así como una correlación positiva entre el uso de tecnología digital educativa y la valoración del software. Los resultados de esta evaluación del software Plectrus respaldan su eficacia y utilidad para el desarrollo de la entonación en instrumentos de viento-metal y cuerda frotada en el nivel inicial de los estudios musicales.
Palabras clave. Entonación, software, instrumentos musicales, nivel inicial de aprendizaje instrumental, tecnología digital.

ENG Music teachers' perceptions of a new software for the assessment of musical instrument intonation

ENG **Abstract:** Intonation is an essential skill to master when learning a musical instrument, especially one with variable intonation, such as a brass or bowed string instrument. A common problem is that beginner students often struggle with the intonation of these instruments during their learning process. As such, they tend to dedicate a large amount of time to practice, while the teaching staff spend a lot of time correcting related errors. This validation study is part of a research project of a broader scope that has designed and implemented a piece of software called Plectrus, for the real-time assessment of intonation in bowed string and brass instrument learning. To understand whether this software met the detected educational needs, a statistical evaluation study was conducted using a questionnaire filled out by teachers from music schools and conservatories in Spain and Chile (n=41). The questionnaire included three dimensions of assessment (technical, educational, and overall). Dimensions on the use of digital educational technology, professional experience, gender, age, and professional training acted as covariates to analyze their influence on the

dimensions of assessment. The quantitative results were triangulated with qualitative data collected from two focus groups (n=10) with the purpose of ensuring the credibility of the interpretation of the results. The results indicate that Plectrus was received very positively by teaching staff in the three dimensions of assessment; positive correlations between the three dimensions were also found, as well as a positive correlation between the use of educational digital technology and the evaluation of the software. The results of this evaluation of the Plectrus software support its effectiveness and usefulness for the development of intonation in brass and bowed string instruments at the initial level of musical studies.
Keywords: Intonation, software, musical instruments, initial level of instrumental learning, digital technology.

Contents: 1. Introduction. 2. Literature review. 3. Methodology. 4. Results. 5. Discussion and conclusions. 6. References.

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1. Introduction

Tuning is an essential skill for players of a musical instrument to master, especially with instruments of variable intonation, such as brass and bowed string instruments. When a person tries to imitate a sound that they have previously heard on their instrument or to read a note that represents a sound of a certain pitch, they must execute a series of mechanisms: one related to perception - the ability to discriminate between two different sounds - and another related to sound production - the ability to reproduce a sound on the instrument - (Morrison and Fyk, 2002). intonation is, therefore, a complex skill needed to master the aforementioned instruments, while in others with fixed pitch (with frets or keys, such as the guitar or piano) it does not necessarily have to be studied or developed. Instrumental intonation represents a significant problem in the catalog of abilities that students learning brass or bowed string instruments must develop. Beginner students have more difficulties learning intonation than advanced students because they do not yet possess the cognitive-motor schemata and mental images necessary to produce a correct sound (Aleman et al., 2000). For this reason, during the initial phase of learning a non-fixed pitch instrument such as those mentioned here, students dedicate a large amount of time to practicing intonation and teachers to correcting errors. We therefore propose that the use of software, such as the one described in this research, could be useful as a support tool in the intonation learning process, as it allows for a real-time evaluation of sound production and offers feedback during instrumental practice. However, it is necessary to verify the effectiveness of this software in the processes of intonation learning through the eyes of music teachers, which is the ultimate objective of this study.

2. Literature review

1.1. Intonation: teaching and learning in instrumental classrooms

The intonation teaching/learning process for musical instruments is highly complex for novice students (Silvey et al., 2019), although it is not equally difficult across all musical instruments. A review of the literature shows the great concern that instrumental intonation represents for both teachers and students (Dai et al., 2015; Fernández-Barros et al., 2020; Julia et al., 2019). This concern is greater for students of non-fixed intonation instruments (Fernández-Barros et al., 2023; Zabanal et al., 2023) since a successful instrumental performance with these instruments depends on correct intonation. What factors determine this difficulty? What should the actors involved in the teaching/learning process do to address it?

In addition to physical factors related to how the instrument is built (Powell, 2010; Schlegel, & Springer, 2018), the mouthpiece (Dalmont et al., 1995), and temperature (Zendri et al., 2015), there are other technical factors that affect intonation, such as the position of the bow (Heyne et al., 2019) or the greater or lesser power/direction of the air column (Bucur, 2019). The external factors require students to have a solid initial theoretical foundation (Nordstrom, & Nordstrom, 2020), for example, on effective embouchure (Powell, 2010) and a reeducation on breath control through non-traditional techniques (Montero and Vincent, 2016). Besides this, some foundations for playing in ensembles are also necessary to avoid intonation problems (Miller, 2022).

The intonation teaching/learning process can be approached from three distinct methodological perspectives: traditional, auditory, and audiovisual. It has been suggested that the first method is less effective because it is based on verbal feedback between teacher and student, which is not always understood by the students (Powell, 2010). Nevertheless, there is some evidence that non-technological approaches can produce positive results (Nápoles et al., 2019). The second method consists of learning by imitation or modeling: the students imitate the teachers or a model recording (Rumjaun, & Narod, 2020). Finally, the audiovisual method uses hardware and/or software as tools for students in perception and production tasks, for example, to visualize the sounds produced and then verify if the result matches the proposed model.

Beyond these didactic approaches, intonation in bowed string instruments is characterized by a relatively slow pattern automation process (López-Calatayud, 2023), suggesting a decrease in the focus of attention during the practice of intonation. For all these reasons, it's reasonable to consider the adoption of alternative forms of intonation work in instrumental classrooms, such as the use of the Plectrus software, which is the object of assessment of this study.

1.2. Software for instrumental intonation

Students in mandatory education systems are demanding an ever-increasing use of digital technologies from teachers, reflecting their omnipresent nature outside the classroom. Teachers must adapt to these evolving student needs, and teachers at music schools and conservatories are no exception. Considering the didactic approaches mentioned above, research on software development focused on general musical practice (Julia et al., 2019; Xu, 2021) and intonation (Gardner, 2020) seems justified. Indeed, some authors (Howard et al.,2007; Welch et al., 1989; Wilson et al., 2008) have investigated this topic with a focus on new tools aimed at improving student autonomy during the learning process, as their intonation can be contrasted with a referential model. Greater autonomy could be achieved through a visualization of the input (visual feedback). This could in turn facilitate intonation and improve a student's notions of low and high (García, 2017). However, even though researchers such as Wilson et al. (2008) and Howard et al. (2007) have pointed out that this visual feedback seems to contribute positively to intonation accuracy, Pardue and McPherson (2019) have found it has no effect and have pointed out that learning could even be negatively affected in certain cases.

An example of software that facilitates the learning and practice of instrumental intonation is Intonia (Agin, 2021), which is designed for violin intonation based on the analysis of visual feedback information (contrast between student input and an exercise model). Another program, aimed at students in the early stages of musical training, is Cantus, which proposes a series of exercises for vocal intonation, each with its respective visual feedback, as well as an exercise editor (Pérez-Gil et al., 2016).

This software was the predecessor to Plectrus, the object of this study. Plectrus allows the training and evaluation of intonation by students of musical instruments with non-fixed tuning (violin, viola, cello, trumpet, French horn, and trombone). As will be seen in the next section, this is carried out in real time and online, through personalized practice, since the software allows you to create and modify exercises and group them thematically through learning units.

1.3. Objectives

The creation of the software Plectrus has been the focus of a research project carried out in recent years in collaboration with teachers and students from music schools in Spain and Chile. However, research on the creation of educational software needs to investigate whether the generated product meets the educational needs of students and teachers, and to do achieve this, the software must be assessed by its users. Given that an assessment on the part of the students has already been carried out (Tejada & Fernández-Vilar, 2023), this study focuses on an assessment of Plectrus by music school teachers. The study applied a statistical methodology based on a questionnaire providing quantitative data, and two focus groups, which provided qualitative data related to teachers' perceptions of the software and were used to triangulate the results.

In short, our objective was to detect and classify the perceptions of teachers regarding the use of the Plectrus software. The following analytical categories were used: 1) technical assessment; 2) educational assessment; 3) overall assessment (benefits, problems, and suggestions).

3. Methodology

3.1. Research design

Design science research methodology (DSRM) is one of the most suitable approaches for the development of artifacts (Peffers et al., 2008). Design Sciences (DS) have as their objective the design and development of artifacts that produce satisfactory results or are adjusted to previously determined objectives. In this case, the adaptation to an educational objective involves a relationship of three elements: "the purpose or goal, the character of the artifact, and the environment in which the artifact performs" (Dresch et al., 2015, p. 56). Each of the phases of this methodology has its own specificities and data collection methods. The three phases in the development of Plectrus are design, implementation, and assessment. The first two adopted methods from quantitative and qualitative paradigms and were examined in other studies (Tejada et al., 2022, 2023).

In the software's teacher-assessment phase, the object of this study, two distinct data collection methods were adopted: 1) a questionnaire-based statistical method, which was drawn up *ad hoc* for this research; and 2) an interpretive focus-group method to gather qualitative data that details teachers' perceptions of the software. This triangulation of methods had two objectives: 1) that the qualitative data would allow us to understand the questionnaire scores in more detail; and 2) to provide greater credibility to the interpretation of results from a small sample of teachers.

3.2. Sample

The sample was composed of 41 volunteer teachers (24 men and 17 women). Of these, 29 were Spanish and 12 were Chilean. The teachers in the sample were aged between 26 and 59 and had between 4 and

30 years of teaching experience (Table 1) and between 4 and 15 years of pre-service musical training. The majority of the sample held a degree in teaching conferred by a conservatory. At the time of the study, the majority of participants were teaching exclusively in music schools (10 music teachers) or conservatories (4), both music schools and conservatories (17), or both music schools and universities (1). The rest were teaching in Secondary Education (1) and on undergraduate university degree courses (8). The selection of participants was non-probabilistic and comprised volunteer teachers who were teaching or had taught classes in one of the six musical instruments that the software addresses.

The participating teachers, who were selected for the instruments they taught and their teaching experience, were informed of their rights (anonymity, privacy, and withdrawal) and signed an informed consent.

Table 1. Data regarding participating teachers.

	$\bar{x}$	SD
Questionnaire (n=41)		
Age	40.49	8.503
Teaching Experience	15.41	8.028
Years of initial musical training	10.66	4.385
2 Focus Groups (n=10)		
Age	39.80	10.15
Teaching Experience	15.40	8.64
Years of initial musical training	13.40	1.89

A total of 10 teachers participated in the two focus groups: 4 women and 6 men aged between 29 and 59 years old, all of Spanish nationality, with between 8 and 14 years of pre-service musical training, and between 5 and 30 years of teaching experience. At the time of the study, all the participants held teaching positions at music schools. The selection of participants was non-probabilistic, based on volunteers. The teaching staff participating in the focus groups did not complete the questionnaire, and thus constituted a separate sample; they did, however, have access to the software, knew in advance the topics that would be discussed at the group meeting, and practiced with the software in order to have an informed opinion before the focus group met.

The project's ethical protocol consisted of an informed consent detailing the objectives, rights (privacy, anonymity, withdrawal, and access to the final investigation report), data custody, data validity and destruction schedule, and a contact address. Since the beginning, the project has been authorized by the Human Research Ethics Committee of the University of Valencia.

3.3. Description of the Software

In order to provide the reader with a better understanding of both the teachers' responses regarding the software in the results section and of the researchers' interpretation of the results, this section will describe some of the main features of the software being evaluated.

Plectrus is an online software designed for the real-time practice and evaluation of intonation on the trumpet, trombone, French horn, violin, viola, and cello, as well as other similar instruments. Its potential target audience is composed of initial- and intermediate-level students of said instruments. The software architecture is based on the client-server model, allowing for communication and data storage between the user and the application.

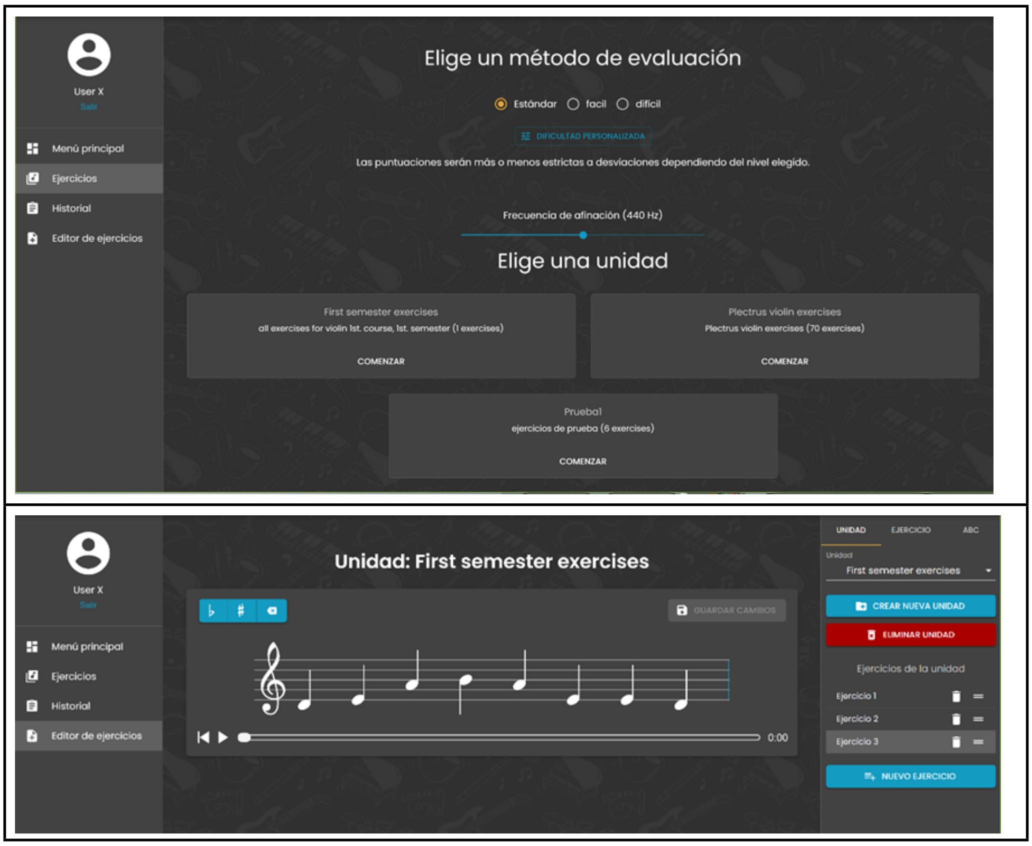
Plectrus picks up the sound of the instrument through the computer microphone, making use of the Web Audio API in the web browser. It then uses an algorithm to determine the frequency of each tone that is played.

The software does not detect the rhythm of the exercise during the evaluation, and the tempo is free. This is to avoid the addition of unnecessary cognitive load that rhythmic learning materials could produce during instrumental practice, as well as to focus the students' attention on the pitch of the sound (Castro-Alonso and Sweller, 2020). During the evaluation, each sound in the reference is assessed independently by an algorithm.

This algorithm can be modified by the student graphically on the home screen, and allows them to configure a personalized evaluation system as they modify the algorithm's sensitivity level. By changing the minimum and maximum frequency deviation thresholds for the sounds introduced, the evaluation becomes more rigorous or permissive: on the evaluation screen (figure 1, left), the intonation deviation limits of the students' responses are adjusted. In short, the permissible threshold is the number of cents below which the exercise is valued without penalty; above this level, the software adds a penalty to the exercise for the deviation, with the "deviation limit" being the maximum value above which the exercise is valued with zero points. The evaluation is carried out in real time and provides the student with two types of feedback. The visual feedback shows a comparison of the waveform of the sound played against the model waveform, with the dashed orange line showing the model to imitate and the solid green line showing the user's input (visual feedback). The "Show evaluation details" drop-down menu provides detailed intonation data for each sound (figure 1, right). This helps identify the differences between one's own interpretation and the correct interpretation.

(fig.1) The evaluation settings screen (left) and final evaluation window of an exercise (right).

Audio and text feedback provides the students with audio and text messages that indicate the errors of each sound played, helping them understand the mistakes they are making and how to correct them. In order for students or teachers to configure personalized practices, Plectrus has sets of sequenced exercises for each instrument, allowing for flexible evaluation with the "custom difficulty" button (figure 2, above). However, practice sessions are not limited by this, as the software also has a section for creating and modifying exercises grouped into thematic units (figure 2, below).



(fig.2) The main exercise selection screen for the violín (top) and exercise creation and editing window (bottom).

3.4. Data collection techniques and instruments

To collect quantitative data, an *ad hoc* questionnaire was designed and implemented by the research team. Furthermore, two focus groups were used for the collection of qualitative data. The questionnaire provided data on the perception of the software and its essential aspects and characteristics, while the focus groups allowed us to understand the reasons why the teaching staff had provided these answers. This overlap of methods was decided on given the scarcity of the sample, with a potential bias that could lead to erroneous interpretations of the results. Thus, data collection methods were triangulated to provide greater credibility to the interpretations of the research group.

The questionnaire included a personal data section to characterize the sample and obtain covariate data (8 items). The rest included closed and open items grouped into 4 scales: 1) experience and use of educational technology by teachers (22 ordinal response items), which was included as a global covariate to correlate with the software assessment dimensions (technical, educational, and global); 2) technical assessment (9 ordinal response items); 3) educational assessment (21 ordinal response items); and 4) overall assessment of the software (8 ordinal response items, 3 binary response items, and 1 scalar response item). In addition, 3 open items called weaknesses, strengths, and suggestions were included. The quantitative items used a 4-point scale (1=a little; 4=a lot) to avoid neutrality, forcing the participants to decide on a pole of assessment (negative or positive) and avoid the routinization of evaluations around the midpoint of the scale. The open-type items were processed together with the rest of the qualitative data. Exceptions to the above were 3 items in the overall assessment dimension that had a binary response option (items 5.9 to 5.11), and another overall assessment item (5.12) that was answered on a 10-point scale due to the teachers' familiarity with this scale.

The questionnaire was validated by two judges, one from Spain and the other from Chile, both university researchers in the area of music teaching with more than 20 years of research and teaching experience in music education. They rated the suitability of the questionnaire to assess software for evaluating instrumental intonation by musical instrument teachers. The judges assessed the questionnaire items and made observations. Subsequently, the research team modified the questionnaire according to these comments and returned the tool to the judges for a second assessment. The correlation between judges was absolute (Kappa Cohen=1).

A descriptive analysis of the variables in the questionnaire was conducted, and then an analysis of the reliability of the scales was conducted based on the analysis of variance. For this, the IBM software SPSS v.28 was used. High reliability was found for the technical, educational, and overall assessment scales (table 2).

Table 2. Questionnaire internal consistency values.

Scale	n	nº of items on the scale	Cronbach's alpha
1. Experience and use of educational technology	41	13	.742
2. Technical assessment	41	9	.893
3. Educational assessment	41	21	.954
4. Overall assessment	41	12	.917

3.5. Procedure

Information about the software design project was disseminated among collaborating institutions, mostly music schools, through a series of software demonstrations. Volunteers were requested through an open call for participants. Once the participating teachers had been selected and informed, they signed the informed consent and proceeded to use Plectrus for the time stated on the information sheet they had been given. Finally, they answered the online questionnaire published on Google Forms.

4. Results

Below are the results of the software assessment. First, we will present the results of the statistical analysis. Following that, we will present the results obtained in the two focus groups before triangulating the data sets in an interpretation of the qualitative data obtained in the focus groups.

4.1. Questionnaire results

4.1.1. Technical assessment results

Before beginning, it must be noted that most of the items in the 3 main assessment dimensions used 4-point scales to avoid neutrality, forcing the participants to choose a pole of assessment.

The technical assessment dimension scored highly across its 9 items ($\bar{x}$=3.55; SD=.461) (table 3). The highest rated item was organization and navigability, followed by ease of use. The lowest valued, meanwhile, was accessibility, i.e. the suitability of the program for use in inclusive education.

Table 3. Item scores in the technical assessment dimension.

Items in the technical assessment dimension (n=41) (range 1-4)	$\bar{x}$	SD
3.1. Effectiveness. It is fit for use in musical intonation.	3.73	.501
3.2. Ease of use. It has a friendly and intuitive user interface.	3.78	.419
3.3. Versatility. It can be adapted to a range of environments, teachers, and apprentice profiles.	3.17	.803
3.4. Accessibility. It has sufficient resources and features to be used in inclusive education.	3.10	.735
3.5. Functionality of the graphical user interface. The GUI is fit for purpose.	3.68	.567
3.6. Suitability, aesthetics, and adequacy of the interface's multimedia language. The interface (language, external appearance, operation of buttons, and program commands) is suitable for use by music students.	3.39	.703
3.7. Organization and navigability. The interface is simple, and easy to understand and navigate.	3.78	.419
3.8. Originality. It is an original and innovative tool for learning intonation.	3.73	.672
3.9. Adaptation to users. It is adapted to the profile and characteristics of the groups that will use it (self-taught students, music school students, conservatories) in initial instrumental learning.	3.59	.706
Overall scores in this dimension	3.55	.461

4.1.2. Educational assessment results

The educational assessment dimension contained 21 items. Items 1 to 16 asked teachers to express their degree of agreement with a statement. Items 17 to 21 asked teachers to assess the usefulness of certain didactic features of the program on a Likert-type scale from 1-of little use, to 4 -very useful. The dimension scored highly in most items ($\bar{x}$=3.53; SD=.474), with the best-rated items being the ability to edit and create exercises, the inclusion of an evaluation sheet showing learning progress, and the ability to configure the accuracy of the evaluation (table 4). The worst-rated item was the tone quality. Regarding items 17 to 21, the participating teachers also valued the educational characteristics of the software very positively ($\bar{x}$=3.51; SD=.531).

Table 4. Item scores in the educational assessment dimension.

Items in the educational assessment dimension (n=41) (range 1-4)	$\bar{x}$	SD
4.1. Learning by modelling. It facilitates learning by imitation.	3.66	.575
4.2. Relevance of contents. The exercises in the program are relevant to musical intonation training.	3.59	.706
4.3. Adaptation of contents. The exercises in the program are suitable for initial instrument training courses.	3.63	.623
4.4. Content usefulness. The contents of the program are useful for practicing musical intonation with instruments.	3.59	.670
4.5. Progression of exercises. It presents the patterns-exercises in a specific order of sounds, which is didactically appropriate for the instrument being used.	3.20	.715
4.6. Usefulness of the user input visualization (student's response and the sounds to be played represented on screen). It is useful to use this visualization.	3.66	.530
4.7. Tone quality. The timbre has no vibrato or sound effects (reverb) and is useful for learning intonation.	2.88	.748
4.8. Evaluation sheet. It fosters control of learning.	3.73	.549
4.9. Feedback (by contrast between the visualization of the user's response against the exercise model + Final reinforcement messages + Notes on whether the sound played was low or high compared to the reference).	3.61	.628
4.10. Exercise editor. It facilitates the customization of training.	3.76	.538
4.11. Initial A_3 frequency setting. It facilitates training with low quality instruments.	3.63	.623
4.12. Separation of intonation from timing. Making timing non-mandatory favors the training of instrumental intonation.	3.44	.838
4.13. Evaluation configurability. The non-mandatory nature of precision (greater or lesser rigor) during the evaluation facilitates the training of novice students.	3.71	.642
4.14. Promotes reflection and learning. It enables autonomous use and provides relevant information for the self-management of instrumental intonation training.	3.49	.675
4.15. Motivation. The software would be motivating and interesting for students.	3.44	.808
4.16. Real-world applicability. Its use in initial music teaching is recommendable as a tool to improve ability with a musical instrument.	3.59	.670
4.17. Sight-reading.	3.56	.594
4.18. Evaluation system.	3.54	.711
4.19. Sequencing of exercises.	3.17	7.38
4.20. Creation of own patterns (exercise editor).	3.76	.435
4.21. Possibility of using this software with other teaching resources.	3.54	.674
Overall scores in this dimension	3.53	.474

4.1.3. Overall assessment results

The overall dimension sought to obtain an integrated, global assessment of the software. It was divided into two parts. The first included 8 items with a 4-point scale and also collected the teachers' assessment regarding specific qualities, expressed through pairs of opposite adjectives (semantic scale) (table 5). The results of these items were very positive ($\bar{x}$=3.51; SD=.53).

Table 5. Item scores in the overall assessment dimension (ordinal scale).

Rating of 8 items with ordinal responses in the overall assessment dimension (n=41; range=1-4)	$\bar{x}$	SD
5.1. Learning by modeling. It facilitates learning by imitation.	3.61	.703
5.2. Relevance of contents. The exercises in the program are relevant to musical intonation training.	3.27	.895
5.3. Adaptation of contents. The exercises in the program are suitable for initial instrument training courses.	3.68	.650
5.4. Content usefulness. The contents of the program are useful for practicing musical intonation with instruments.	3.63	.662

Rating of 8 items with ordinal responses in the overall assessment dimension (n=41; range=1-4)	x̅	SD
5.5. Progression of exercises. It presents the patterns-exercises in a specific order of sounds, which is didactically appropriate for the instrument being used.	3.63	.581
5.6. Usefulness of the user input visualization (student's response and the sounds to be played represented on screen). It is useful to use this visualization.	3.51	.711
5.7. Tone quality. The timbre has no vibrato or sound effects (reverb) and is useful for learning intonation.	3.10	.539
5.8. Evaluation sheet. It fosters control of learning.	3.66	.530
Overall scores in this dimension (8 items)	3.51	.530

The second part of this dimension included 3 binary response items (items 5.9 to 5.11) (table 6) and a final item that was answered on a 10-point scale in order to have a more precise idea of the teachers' assessment, given that this is the scale that is usually used in Spain in academic evaluation. The responses here were very positive and reflect a good reception of the software among teachers.

Table 6. Scores for the 3 binary response items in the overall assessment dimension.

Three items in the overall assessment dimension (n=41) (range: 0-1)	Yes	No
5.9. Do you think that the use of Plectrus can produce a positive impact in the development of intonation skills in beginner students learning an instrument? (yes-no).	97,5%	2,5%
5.10. Would you recommend it to your colleagues? (yes-no).	97,5%	2,5%
5.11. Do you think that the use of Plectrus can have a positive impact in the development of Elementary Music Education students' reading skills? (yes-no).	100%	0%

The last item in this dimension asked teachers to rate the software on a 10-point scale. The result here was also positive (x̅=8.44; SD=1.44) and was consistent with the assessment on the 4-point scale of items 1 to 8 of the dimension.

Table 7. Correlations of the dimensions of assessment.

		Technical assessment	Educational assessment
Educational assessment	Pearson's r	0.887	--
	gl	39	--
	p	<.001	--
Overall assessment	Pearson's r	0.784	0.911
	gl	39	39
	p	<.001	<.001

Finally, it should be noted that the three dimensions of software evaluation correlated positively, with statistically significant differences that cannot be explained by chance (table 7).

4.1.4. Covariates

Along with the three dimensions or categories of assessment: 1) technical assessment; 2) educational assessment; and 3) overall assessment, some covariates have been considered that could have systematically influenced these dimensions: 1) teachers' experience and use of educational technology; 2) gender; 3) nationality; 4) extent of initial training; and 5) teaching experience.

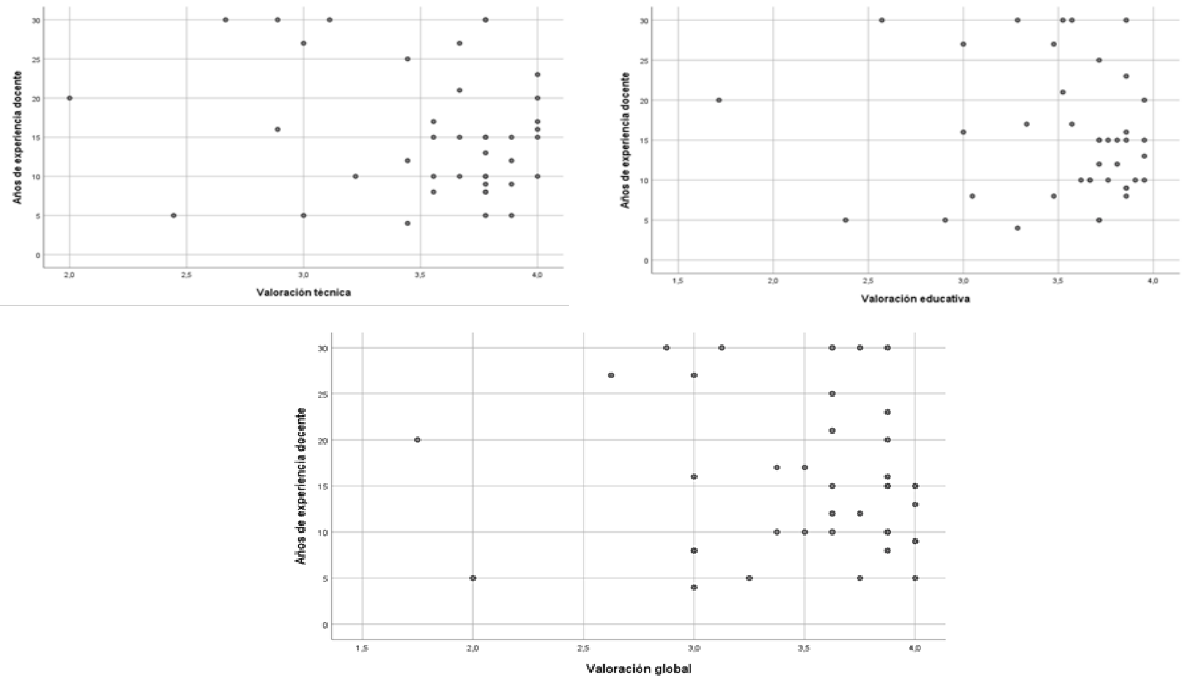
Likewise, a dimension with 9 items was included in order to understand the teachers' experience and use of educational digital technology and whether this covariate had an influence on the results through its correlation with the evaluation dimensions. The results show high values (table 8). The correlations between this covariate and the software evaluation dimensions are medium-sized positive results (between 0.3 and 0.5) with significant positive differences. This means that the greater the teachers' experience in using educational technology, the higher the scores they gave in the technical, educational, and overall evaluation dimensions.

Table 8. Assessment of the questionnaire dimensions (4-point scale), Pearson's r correlations, and bilateral significance between the covariate of experience using educational digital technology and the software assessment dimensions (statistical significance *p>0,05; **p>0,01).

Scale	n	x̅	SD	Pearson's r	p value (bilat.)
Experience and use of educational technology	41	2.23	.367	--	--
Technical assessment	41	3.55	.461	.388	.012*
Educational assessment	41	3.53	.474	.449	.003**
Overall assessment	41	3.51	.531	.359	.021*

Gender had no influence on the technical and educational assessment dimensions, but it did have an influence on the overall assessment dimension, with women scoring higher than men (t=-2.33; p=0.025).

The covariates of nationality and extent of initial training had no influence on the assessment dimensions. Teaching experience was a covariate that showed statistically significant differences in relation to the three dimensions of software assessment: technical assessment (χ^2=34.7; gl=20; p=0.021), educational assessment (χ^2=58.2; gl=20; p <.001), and global assessment (χ^2=70.7; gl=30; p< 0.001). The more years of teaching experience a participant had, the higher they rated the software (figure3).



(fig.3) Cross-tabular graphs showing the teaching experience covariate against each of the three Plectrus software assessment dimensions: technical (top left), educational (top right) and overall (below).

4.2. Focus group results

The focus group results are presented below following an analysis of the qualitative data based on previous analytical categories derived from the dimensions of the questionnaire. The objective was to detect and classify teachers' perceptions regarding the use of the Plectrus software, and to relate these results with those from the questionnaire (triangulation of methods). These analytical categories are: 1) technical assessment; 2) educational assessment; 3) benefits, problems, and suggestions.

In the focus groups, the researcher gradually introduced previously validated topics that provided a lot of information by drawing out other topics that had not initially been considered. The videos of these focus group sessions were analyzed using the Elan software, with codes assigned to quotes from different levels of analysis. All of this produced the results presented in the following sections.

4.2.1. Technical assessment results

In general, the participants expressed very positive opinions regarding the technical aspects of the software. A majority of participants stated that accessing the program was intuitive and simple, and that the graphical user interface was easy to navigate. They also agreed that the software allows for the adaptation of exercises depending on the academic level and the instrument in question. They stated that the immediate evaluation of the exercises and the ability to contrast the students' sound response with a model on the screen offered students constructive and beneficial feedback: "We are, of course, accustomed to the use of different software and this one seemed very easy to use" (prof. 4, focus group 2). Likewise, the need to reconfigure the graphical user interface was highlighted because, in the participants' opinions, a design that is more in line with the age of the students could increase the level of acceptance in both boys and girls in the software's target age bracket. In general, the participants highlighted the value of the software as a very useful auxiliary tool for work related to instrumental intonation: "I think that it's a very intuitive software with a very clean design that helps with its application in the classroom" (prof. 1, focus group 1). These opinions triangulate very well with the results collected in the technical assessment questionnaire, which, overall, obtained high scores ($\bar{x}$=3.55; SD=.461), especially in the items regarding organization, navigability, and ease of use ($\bar{x}$=3.78; SD=.419), all vital elements to the success of a software.

4.2.2. Educational assessment results

In terms of its educational assessment, the software also received very positive comments in the focus groups, again triangulating well with the data obtained from the questionnaire ($\bar{x}$=3.53; SD=.474). Several participants agreed that Plectrus could help strengthen tuning skills through individual and prior study, before a student is asked to tune up in a group performance: "Having a more developed auditory sensitivity when playing in a group helps" (prof. 1, focus group 1). Likewise, other teachers said they believed that the ease of use of the software by students could facilitate their autonomy when practicing from home. The creation of a practice history for each student allows for much more personalized monitoring, always adapted to each student: "Also, the didactic progression, the fact that you have a history that allows you to see that you are improving little by little, facilitates a greater perception of the progress made by the students" (prof. 4, focus group 1). This opinion coincides with the potential of musical practice software to facilitate the development of student self-regulation strategies (López-Calatayud & Tejada, 2024, in print) when they begin to learn an instrument.

The participants also spoke highly of the ability to create and edit exercises, which was a didactic feature considered among the software's greatest strengths. This feature is what makes the software an open tool for both teachers and students with the ability to set up their own practice itinerary, instead of being a closed system with pre-programmed exercises decided on by the designers, as is the case with other music training software. The feature also facilitates a precise adaptation to the academic level of each user and aids the educator in the creation of a weekly plan, if deemed appropriate. Furthermore, it allows the teacher to monitor progress and take into account the emerging difficulties faced by their students: "[...] unlike working with a typical tuning device where you only see an arrow indicating a point, this software visually allows you to see the problems in greater detail, and thus be able to react and learn" (prof. 1, focus group 2). These statements triangulate well with the high scores assigned to this feature in the educational assessment dimension of the questionnaire (table 5, item 4.10).

Some teachers stated that, given the scarcity of computer programs supporting the practice of instrumental intonation, this software should be considered essential for learning musical instruments of non-fixed pitch. These statements triangulate well with the questionnaire data from the technical assessment dimension.

Furthermore, some commenters also mentioned that the tool's specificity could act as a pedagogical incentive for students, especially for beginners: "Normally, students do not start by studying intonation. So, applications like this, that are focused on intonation, can serve as a guide for students and can be a good reference" (prof. 2, focus group 2).

Being able to configure the evaluation system was among the items most highly valued by teachers. The same was true in the questionnaire results ($\bar{x}$=3.71; SD=.642). The fact that the evaluation can be made more or less precise can favor practice and increase the motivation of novice students. A fixed strict evaluation could be demotivating for younger students and could cause them to abandon a practice session: "being able to customize the error range within the application seems very important to me in terms of motivation. We cannot demand the same level from a student who is just starting out with the instrument as from another with a higher level" (prof. 3, focus group 2). This triangulates well with the results from the educational assessment dimension (item 4.13 of the questionnaire).

4.2.3. Perceptions regarding benefits, problems, and suggestions

The teachers emphasized the advantages of the graphic visualization of the pitch of the sound (non-notational) as an element that allowed them to see and precisely correct any difficulty that appeared in the intonation task: "often, students are not aware that when passing from one note to another, you can observe the entire process with the [sound] graph" (prof. 2, focus group 1). This positive evaluation of visual feedback stands out as a finding of this study.

The majority of participants expressed an extremely favorable perception of the software, without identifying significant problems. However, a number of suggestions were made during the focus groups that, from an analytical perspective, could be interpreted as areas for improvement. In terms of working with specific instruments, such as the violin, participants recommended adapting the software to evaluate techniques such as the use of double strings. Finally, they emphasized the importance of expanding the applicability of the software to other instruments, especially to those of the woodwind family.

Regarding didactic suggestions, some teachers proposed the incorporation of rhythmic elements to the intonation exercises to improve their integrity. This suggestion is reviewed in the discussion section.

As mentioned, some educators highlighted the need to reconsider the graphical user interface, as well as improving its adaptation to mobile devices such as tablets and phones. They also proposed the implementation of a reward system based on medals or achievements to encourage user motivation. Regarding sound inputs, the problem of reverberation in certain spaces was mentioned, and participants recommended the integration of an external microphone that would allow for a more reliable reception of the instrument's sound. Finally, participants mentioned that the platform could offer a feature for the creation of student and teacher profiles in order to facilitate more precise and personalized monitoring of students and their progress.

5. Discussion and conclusions

This study aimed to evaluate an online software called Plectrus,[1] which was designed as a software solution for the real-time training and evaluation of beginner student intonation on brass and bowed string instruments. The positive results obtained, by both quantitative and qualitative data collection methods, indicate that Plectrus responds well to the needs detected prior to the software's design (Tejada et al., 2022), and that it has met the functionality objectives of design science research methodology: It has been assessed very positively by the teaching staff in the three assessment dimensions of this study.

The findings of this research show parallels with another previous study that addressed the design and assessment of software for musical learning processes, specifically the software called Cantus, which is intended for vocal intonation and aimed at students at music schools and conservatories (Pérez-Gil et al., 2016). The teachers who participated in that study favorably evaluated the technical, educational, and overall aspects of the software, affording high scores across the board (above 4 points on a 5-point rating scale). Among the most highly valued aspects were the software's applicability, effectiveness, originality, navigability, and organization. Additionally, all the participants stated that they would recommend the software and that they believed the software would positively impact the development of voice intonation.

Cantus' greatest strengths, as mentioned by teachers, coincide with those of Plectrus: the ability to carry out autonomous musical practice without the teacher, with the software correcting intonation problems, gives information to the student (automatic evaluation) and shows a contrast between the representation of musical responses and the model the student should be imitating (visual and aural feedback) (Howard et al.,2007; Welch et al., 1989).

Some teachers suggested the incorporation of rhythmic elements into the exercises to improve their integrity. However, some researchers (Bengtsson and Ullen 2006) have argued for the convenience of dissociating rhythm and intonation in instrumental practice for rapid learning and the development of flexibility in motor control. This suggestion is based on the fact that the two types of information are processed in different parts of the brain. Additionally, it could represent an added cognitive load for novice students as they face several simultaneous problems: reading, perception, and rhythmic production tasks alongside the homonymous intonation tasks. As a result, a student's attention could be divided to the detriment of their learning (Castro-Alonso and Sweller, 2020). Thus, the presentation of rhythm alongside intonation during the early stages of instrumental learning may not be the most appropriate didactic choice if the aim is for students to focus their attention on intonation processes. In this case, it is most convenient to separate practice into specific rhythm and intonation exercises.

One of the findings of this study was the positive assessment of visual feedback. It triangulates well with the high scores in item 4.6 of the questionnaire (table 5), as well as with the result of the evaluation of the Cantus software (Pérez-Gil et al., 2016).[2] However, this concept shows inconsistent results in the literature (Blanco and Ramírez, 2019; Howard et al.,2007; Pardue and McPherson, 2019; Welch et al., 1989; Wilson et al., 2008), so this finding should be interpreted with caution.

A finding for which a plausible explanation cannot be found is the higher score of women compared to men in the overall assessment dimension of the software. It cannot be explained with the data obtained (there is no correlation of this dimension with the technical or educational dimensions) nor with the related literature. We suspect that it could be a consequence of the size of the sample used.

An important aspect to highlight is the capacity of the Plectrus software to facilitate autonomous practice for students, i.e., working with the instrument without a teacher present, by offering an automatic evaluation of tuning, an analysis of the problems that have arisen, instant information for students, and a visualization contrasting student production against the ideal intonation model (visual and aural feedback).

In summary, and although the sample used in the questionnaire could be considered limited, and therefore a limitation of this study, data triangulation between the questionnaire results and the results of the focus groups shows consistency. The results of this research indicate that the software produces satisfactory results and is adjusted to the initial objectives of the DSRM. Therefore, the results support the effectiveness and usefulness of Plectrus as a valuable tool for the development of intonation on brass and bowed string instruments at the initial level of musical studies. These findings align with previous research on music teaching processes (Pérez-Gil et al., 2016; Tejada et al., 2011), suggesting that the use of specialized software could have a positive impact on the musical learning process and, in this case, on the improvement of intonation skills.

To confirm this assumption, we propose a series of small-scale studies – the only ones viable in the educational context of music schools and conservatories – with cumulative data collection in order to assess the external validity of the results, which constitutes a limitation of this study. It would also be important to carry out studies on the effect that instrumental practice with Plectrus has on intonation skills, as well as more qualitative studies to see how the use of this resource affects certain psychological constructs and students' emotions when using Plectrus in instrumental practice. This has already been done discreetly in relation to some psychological constructs, such as strategies, self-regulation (López-Calatayud & Tejada, 2022), and self-efficacy (López-Calatayud & Tejada, in press), but there are others whose relationship with learning resources could make valuable contributions to the knowledge of the processes of intonation skill development.

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1 https://www.plectrus.com
2 https://www.cantus.es

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