Enhancing Second and Foreign Language Motivation through STEAM: An Action Research Study in an International School in Morocco

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Recepción: 13.04.2025 | Aceptado: 24.04.2025

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Citar: El Jazzar, S (2025). Enhancing Second and Foreign Language Motivation through STEAM: An Action Research Study in an International School in Morocco. *REIDOCREA, 14*(15), 218-232.
Estudio de investigación de Doctorado
Área o categoría del conocimiento: Didáctica de lenguas extranjeras / Multidisciplinar

Abstract: STEAM (Science, Technology, Engineering, Arts, and Mathematics) education has gained international recognition for fostering interdisciplinary learning, creativity, and student engagement. However, its implementation in second and foreign language instruction remains limited, especially in multilingual international contexts. This study explores the effects of implementing a STEAM-oriented instruction in French and Arabic classes at an American international school in Morocco. Using a mixed-methods, action research design, this study draws on pre- and post-intervention surveys and student focus groups to examine how such instruction influences motivation and classroom engagement. The findings indicate that while integrative and instrumental motivation showed minimal change, learners demonstrated increased interest, participation, and emotional investment when engaged in interdisciplinary, project-based language tasks. These results point to the potential of STEAM-based instruction to enhance short-term motivation and enrich the language learning experience. However, they also underscore the importance of pairing STEAM approaches with targeted, language-focused instructions to achieve sustained language development. The study contributes to emerging research on innovation in language education and offers insights for applying interdisciplinary pedagogies within global, multilingual school settings.

Keyword: STEAM Education

Introduction

The increasing emphasis on 21st-century skills has led many educational systems to adopt interdisciplinary teaching models that prioritise creativity, critical thinking, and meaningful problem-solving. One such model that has gained widespread recognition is STEAM (Science, Technology, Engineering, Arts, and Mathematics), which expands the STEM framework by including the arts. This approach encourages deeper conceptual understanding and learner engagement through integrated, inquiry-driven instruction (Yakman, 2008; Moore et al., 2014). While STEAM has been broadly applied in scientific and technical disciplines, its use in foreign language education remains relatively underdeveloped—particularly in international and multilingual school contexts, where language learning is a vital part of students' academic and intercultural development.

In second and foreign language education, motivation is widely recognised as a decisive factor in language acquisition. Gardner's (1985) socio-educational model laid an essential foundation for understanding how learners' attitudes and aspirations—whether integrative or instrumental—shape their language learning behaviours. Dörnyei's (2009) L2 Motivational Self System expanded this understanding, introducing the concepts of the ideal L2 self, the ought-to self, and the L2 learning experience. These components reflect how internal self-concepts interact with external pressures and classroom realities. In parallel, Deci and Ryan's (1985) self-determination theory draw a distinction between intrinsic motivation—rooted in curiosity and enjoyment—and extrinsic motivation, which is tied to external goals and rewards. Together, these frameworks offer a comprehensive perspective on what drives language learners and how classroom environments can nurture or inhibit their motivation.

Beyond motivation, learner engagement also plays a vital role in successful language development. As Dörnyei (2019) explains, engagement encompasses cognitive, emotional, and behavioural dimensions that determine how learners interact with the language, their peers, and the instructional materials. Svalberg (2009) describes it as a state of "alertness" that fuses attention, emotional investment, and social interaction. Ellis (2010) adds that engagement influences how learners respond to feedback and adjust their language use. These interpretations suggest that rich, interactive environments are necessary to sustain learners' interest and effort over time.

Recent research has begun to explore how STEAM-based instruction may help create these kinds of environments. Ng and Fergusson (2020), for instance, found that high school students gained confidence and interest when engaging in STEAM tasks that bridged disciplinary boundaries. Lin and Tsai (2021) similarly noted that the collaborative and creative elements of STEAM helped learners develop project management skills and deeper academic engagement. In language learning contexts, Schoettler (2015) observed that students in German classes retained vocabulary more effectively when it was taught through STEAM-based activities. Pugar, Haristiani, and Herniwati (2021) reported similar findings in online Japanese lessons, where learners improved their speaking fluency and digital literacy through context-rich, interdisciplinary tasks.

Other studies point to the positive emotional and cognitive impacts of STEAM. For example, Jia, Zhou, and Zheng (2021) found that integrating STEAM with Maker education improved primary students' motivation and sense of ownership over their learning. Asigigan and Samur (2021), working in a Turkish context, observed increases in intrinsic motivation and problem-solving ability among learners who participated in gamified STEAM projects. These findings suggest that STEAM does more than integrate disciplines; it creates conditions that are conducive to both skill development and affective engagement.

In light of this research, it seems clear that STEAM has untapped potential in second and foreign language classrooms—particularly when instructional activities are grounded in real-life challenges and designed to connect linguistic goals with broader competencies. As supported by theories such as Self-Determination Theory (Ryan & Deci, 2000), learning environments that nurture autonomy, competence, and relatedness are more likely to spark intrinsic motivation and sustain engagement over time.

Given Morocco's multilingual setting, the distinction between second and foreign language instruction is crucial in this study. Arabic is considered a second language, given its official status and daily use in education, media, and public discourse. French, by contrast, is typically treated as a foreign language in English-medium international schools, where exposure is mostly limited to the classroom. This difference in status and usage inevitably influences students' perceptions of each language's value and their corresponding motivation levels.

This study contributes to that growing conversation by exploring how a STEAM-based unit—developed for Arabic and French classes at an international school in Morocco—affected student motivation and engagement. The study adopts a mixed-methods action research design, with pre- and post-intervention questionnaires and focus groups used to capture shifts in learner motivation and classroom participation. It builds on a context where learners face multiple linguistic realities and where traditional approaches to language instruction often fall short of engaging students meaningfully.

The intervention was designed following principles of action research, with the teacher acting as a reflective practitioner to address specific pedagogical challenges. Through

iterative cycles of planning, implementation, and evaluation, the unit aimed not only to integrate science, ecology, and technology with language instruction, but also to shift students' perception of language learning from a purely academic exercise to a functional, real-world tool. This research, therefore, offers both theoretical insights into the motivational effects of interdisciplinary teaching and practical examples for language educators seeking innovative approaches in multilingual classrooms.

Method

This study was conducted through a classroom-based action research design led by the teacher-researcher, with the goal of exploring how STEAM-integrated instruction could influence students' motivation and engagement in French and Arabic classes. The project was implemented in an American international school in Morocco, with 24 students between the ages of 12 and 14 participating in the study. These students represented a linguistically and culturally diverse group, holding Moroccan, French, Spanish, British, American, Swedish, and Syrian nationalities. English was the main language of instruction at the school, while French and Arabic were taught as additional languages.

The pedagogical intervention was structured as a six-week STEAM-based instructional unit grounded in constructivist, inquiry-based learning principles (Bybee & Landes, 1990). Students were tasked with investigating and supporting bird biodiversity on their school campus, a real-world ecological issue that framed the instructional sequence. The unit unfolded in three interrelated phases and was designed to simultaneously promote scientific inquiry and language development in French and Arabic.

The first phase was launched during a temporary school closure and delivered remotely. Students used digital mapping tools and satellite imagery to identify areas on campus suitable for bird observation. In addition to developing spatial awareness and digital literacy, they engaged with environmental literature and multimedia resources, including Rachel Carson's *Silent Spring* and a documentary on endangered bird species. These materials helped students generate inquiry questions collaboratively. Language instruction in this phase focused on vocabulary related to ecology, bird anatomy, and environmental challenges, with grammar practice (such as adjective agreement) embedded within meaningful contexts.

In the second phase, which resumed in-person, students observed bird species in their natural habitat on campus, using identification apps (BirdNet, Merlin Bird ID), cameras, and journals to document their findings. They categorized bird species, developed maps, and presented findings through graphs and written descriptions. French and Arabic were used throughout to label, interpret, and communicate data, reinforcing their practical use in an authentic scientific investigation.

The third phase involved planning and building bird feeders. Students drew upon their data to design feeders that met the needs of observed species, integrating knowledge from ecology and engineering. Language tasks during this phase included describing materials and methods, justifying design decisions, and presenting final products. Students also monitored feeder effectiveness and wrote reflective reports in the target languages.

The sequence concluded with presentations and reflective discussions in which students assessed the impact of their designs and their own learning process. They used French and Arabic to explain results, express opinions, and propose improvements. This final phase emphasized extended language production for justification and critical thinking.

Across the unit, students experienced language as a tool for solving real problems, collaborating with peers, and expressing complex ideas. The unit embedded linguistic skills in inquiry-based, interdisciplinary contexts, showing how STEAM can enhance both motivation and meaningful communication in language learning.

A total of 24 students took part in the study: 15 boys and 9 girls. Most were multilingual, navigating between Moroccan Arabic (Darija), Modern Standard Arabic (MSA), French, English, and sometimes Amazigh or Spanish. The school's multilingual environment, coupled with students' diverse linguistic experiences at home and in previous schooling, shaped the context of language learning in meaningful ways. MSA was often regarded as a formal or distant variety, while French, although sometimes a heritage language, was typically confined to the classroom in this English-medium school. These distinctions informed students' perceptions of each language and their motivational orientations.

A mixed-methods design was used to collect and analyse data. Two main tools guided data collection: surveys and focus groups. The first survey, distributed before the intervention, collected demographic information and explored students' attitudes toward French and Arabic. Open-ended questions asked about language learning goals, perceived challenges, enjoyment, and relevance.

The second instrument was a modified version of Gardner's (1985) Attitude/Motivation Test Battery (AMTB), adapted to assess five constructs: integrative motivation, instrumental motivation, general interest, motivation intensity, and classroom anxiety. The AMTB was administered both before and after the unit to track any shifts in motivation.

In addition, two rounds of focus group discussions were held. The first, conducted mid-way through the unit, asked students to reflect on their experiences so far—what they found interesting or difficult, and how the integration of ecological themes affected their engagement. The second took place at the end and invited learners to assess how the unit shaped their motivation, interest, and confidence in learning French or Arabic.

Quantitative data from the AMTB were analysed using SPSS. Descriptive statistics were calculated for each construct at both time points, and paired-sample t-tests were used to identify statistically significant changes. These helped determine whether STEAM-based learning had a measurable effect on students' motivational profiles.

The qualitative data—drawn from focus group transcripts and survey responses—were analysed using Creswell's (2014) six-step process. The researcher first transcribed the discussions and then coded the data manually to stay close to participants' voices. Codes were drawn from the literature on second language motivation and engagement, focusing on themes such as integrative and instrumental goals, emotional involvement, confidence, anxiety, collaboration, and perceived relevance. Subthemes emerged during analysis, including students' appreciation of hands-on learning, enjoyment of teamwork, and increased willingness to use the target language.

Coding was refined and organized using Atlas.ti software, which facilitated comparisons across time points and between language groups. The process combined deductive and inductive strategies, allowing patterns to emerge while staying aligned with theoretical constructs. Triangulating findings from both quantitative and qualitative sources gave a richer understanding of how interdisciplinary, project-based instruction shaped learners' attitudes and participation in language learning.

This methodology provided insight into how learners respond to innovative, cross-disciplinary approaches and how such designs can support the development of both linguistic competence and learner motivation in complex multilingual classrooms.

Results

This section presents the results of the study examining how STEAM-integrated instruction influenced student motivation in French and Arabic language classes at a multilingual international school. The findings are organized to reflect the mixed-methods design: quantitative results from the Attitude/Motivation Test Battery (AMTB) are followed by qualitative insights drawn from the survey and the two rounds of student focus group discussions. The quantitative analysis reveals modest shifts in students' motivational orientations following the STEAM intervention, with a significant increase in interest in language learning, while other dimensions—such as integrative and instrumental goals, effort, and language-related anxiety—remained largely stable. The qualitative data further contextualize these trends by capturing students' perspectives on how the project-based, interdisciplinary approach shaped their classroom experiences and attitudes toward language learning.

Quantitative results from the Attitude/Motivation Test Battery (AMTB) revealed differing patterns of motivational change in the French and Arabic language classes following the STEAM-integrated instructional sequence. This section presents descriptive and inferential statistics for each class, followed by a discussion of student-reported experiences drawn from focus group discussions. In the French class, the descriptive statistics indicate minor to moderate changes across several motivational dimensions. As shown in Table 1, there was a decline in motivation intensity from a pre-intervention mean of 3.25 (SD = 0.65) to 2.44 (SD = 0.71), and in interest in foreign languages from 4.00 (SD = 0.60) to 3.64 (SD = 0.55). Attitudes toward learning French and desire to learn French declined slightly, while integrative and instrumental motivation remained stable. Classroom anxiety also showed a modest reduction. Teacher evaluation scores improved.

Table 1.
Descriptive Statistics for Motivation Dimensions – French Class (N = 24)

Category	Pre-STEAM implementation mean	Post-STEAM implementation mean
Integrative motivation	2.09 (0.91)	2.00 (0.93)
Instrumental motivation	2.27 (0.88)	2.27 (0.84)
Attitude towards learning French	3.56 (0.80)	3.42 (0.67)
Desire to learn French	2.88 (1.00)	2.79 (0.97)
Interest in foreign languages	4.00 (0.60)	3.64 (0.55)
Motivation intensity	3.25 (0.65)	2.44 (0.71)
French class anxiety	3.54 (0.51)	3.34 (0.52)
French use anxiety	2.55 (0.54)	2.52 (0.50)
French course evaluation	2.98 (0.34)	2.94 (0.37)
French teacher evaluation	2.98 (0.77)	3.50 (0.93)

To assess the statistical significance of these changes, paired-sample *t*-tests were conducted. Results are displayed in Table 2.

Table 2.
Paired-Sample t-Test Results and Effect Sizes – French Class (N = 24)

Category	T-statistic	P-value	Cohen's
Integrative motivation	0.54	.60	-0.1
Instrumental motivation	0	1.00	0
Attitude towards learning French	1.04	.31	-0.19
Desire to learn French	0.47	.64	-0.09
Interest in foreign languages	3.43	.01	-0.81
Motivation intensity	5.43	< .001	-1.48

French class anxiety	2.07	.05	-0.39
French use anxiety	0.28	.78	-0.06
French course evaluation	0.46	.65	-0.11
French teacher evaluation	2.79	.009	0.64

These results indicate that the STEAM-based instruction in French led to a significant decline in motivation intensity and interest in language learning more generally. However, student anxiety decreased, and teacher evaluations improved, suggesting positive affective responses despite lower sustained motivation.

In the Arabic class, the descriptive results point to more positive trends. Table 3 presents the means and standard deviations for all motivational dimensions. Interest in foreign languages and motivation intensity both increased, while integrative and instrumental motivation showed moderate improvement. Anxiety and course evaluations remained mostly stable, with slight gains in students' perceptions of the teacher.

Table 3.
Descriptive Statistics for Motivation Dimensions – Arabic Class (N = 24)

Category	Pre-STEAM implementation mean	Post-STEAM implementation mean
Integrative motivation	2.14 (0.90)	2.33 (0.81)
Instrumental motivation	1.60 (0.55)	2.02 (0.72)
Attitude towards learning Arabic	2.35 (0.69)	2.55 (0.87)
Desire to learn Arabic	2.08 (0.94)	2.17 (1.15)
Interest in foreign languages	2.08 (0.94)	2.92 (0.52)
Motivation intensity	2.08 (0.89)	2.33 (0.49)
Arabic class anxiety	1.97(0.77)	1.98 (0.64)
Arabic use anxiety	1.39 (0.83)	1.53 (0.64)
Arabic course evaluation	1.88 (0.89)	2.26 (0.75)
Arabic teacher evaluation	2.78 (1.03)	2.95 (0.72)

Table 4 summarizes the statistical testing for these measures.

Table 4.
Paired-Sample t-Test Results and Effect Sizes – Arabic Class (N = 24)

Category	T-statistic	P-value	Cohen's
Integrative motivation	0.54	.60	0.22
Instrumental motivation	1.61	.12	0.33
Attitude towards learning Arabic	0.62	.54	0.25
Desire to learn Arabic	0.21	.84	0.09
Interest in foreign languages	2.71	.01	1.15
Motivation intensity	0.85	.41	0.35
Arabic class anxiety	0.03	.98	0.01
Arabic use anxiety	0.46	.65	0.19
Arabic course evaluation	1.13	.27	0.46
Arabic teacher evaluation	0.47	.64	0.19

These findings show a significant increase in students' interest in learning languages following the STEAM project, with a large effect size (d = 1.15). Other areas, including motivation intensity and instrumental motivation, trended upward though not significantly. Students' affective responses and perceptions of instruction remained largely consistent, suggesting a more balanced outcome compared to the French class.

Student perspectives gathered through focus group discussions offered valuable insights into how STEAM-based instruction shaped their motivation, interest, and attitudes toward learning French and Arabic. The focus groups were conducted in two phases: the first mid-way through the instructional sequence and the second at its conclusion. These discussions explored students' evolving perceptions of language learning within the STEAM framework, revealing both enthusiasm for project-based approaches and suggestions for pedagogical improvement. Many students reported that the

interdisciplinary project helped make language learning more meaningful by connecting it to real-world topics. Themes of engagement, collaborative learning, and contextual relevance emerged frequently. Several students expressed appreciation for the creative, hands-on tasks, emphasizing that learning about biodiversity in French allowed them to "learn French while doing something new," rather than treating language as an isolated subject. As one student stated, "I liked how we worked in groups and learned about birds at the same time. It wasn't just about learning French—it was doing something with it". Students also highlighted the affective benefits of STEAM activities. Many felt that they could participate more actively and confidently in group discussions, especially when tasks were open-ended, and inquiry driven. Some participants specifically contrasted this with more conventional grammar-focused lessons, which they found less engaging. However, there were also reservations: a number of students indicated that while the STEAM unit increased their enjoyment and willingness to participate, it did not always provide sufficient scaffolding for grammar or writing development. One student noted, "It was fun, but I still need more help with grammar and writing—we didn't really focus on that."

These reflections point to an important nuance: students valued the motivational and creative aspects of the STEAM project but recognized a need for more structured support in core linguistic competencies. Several students proposed integrating both approaches—creative projects and targeted grammar instruction—to balance motivation with skill development. In the Arabic focus groups, students likewise emphasized the novelty and enjoyment of learning outside the traditional classroom. Many spoke positively about working in nature, observing birds, and applying Arabic vocabulary to describe their findings. One student remarked, "We learned Arabic through experience, not only through reading and writing," suggesting that the shift in context helped them see the practical relevance of the language. Students also reported increased motivation and interest, particularly in the early stages of the project, where they were engaged in observation and data collection. However, like their peers in the French group, several noted the challenge of maintaining target language use during collaborative tasks, especially when working in groups where English or dialect Arabic was more commonly spoken. One student explained, "Sometimes we used English to communicate during the project. It helped the task but maybe didn't help our Arabic as much". Students appreciated the emphasis on group collaboration and experimentation, with one participant stating, "We worked in small and large groups, not like always doing drills. It felt like we were doing something important." However, they also acknowledged that language development in formal areas—such as grammar, reading comprehension, and structured writing—might require more explicit instruction alongside project-based learning.

Discussion

This study examined the effects of a STEAM-integrated instructional unit on student motivation in French and Arabic classes at a multilingual international school in Morocco. Developed and implemented by the teacher-researcher through an action research model, the intervention offered valuable insights into how interdisciplinary, project-based learning environments can shape students' attitudes toward language learning. The results highlighted both promising outcomes and notable challenges.

A closer analysis of the data revealed contrasting patterns between the two language groups. In the French class, quantitative results showed a decrease in motivation intensity and general interest in foreign languages following the intervention. While students expressed enjoyment of the creative and collaborative aspects of the project, many felt that it lacked the structure they associated with measurable linguistic progress,

especially in areas like grammar, writing, and fluency. These perceptions were echoed in focus group discussions, where learners described the experience as engaging but not rigorous enough to support tangible improvement in their French skills. This finding aligns with Dörnyei's (2009) perspective that motivation is not sustained by engagement alone but also relies on students' perception of goal achievement and language development.

In contrast, students in the Arabic class reported more positive shifts in motivation. While the gains in motivation intensity were less dramatic, learners described the experience as meaningful, particularly when Arabic was used in the context of environmental exploration and local biodiversity. These responses suggest that Arabic, despite its more formal register in Modern Standard Arabic (MSA), carried a stronger emotional and cultural connection for students during the project. Many learners associate Arabic with home, religion, and family life, making it a more personally relevant language for integrative motivation. French, on the other hand, is often perceived as an academic subject or a tool for international mobility, which may lack immediate emotional resonance in this particular context.

Instructional background also appeared to influence how the STEAM sequence was received. Arabic classes at the school traditionally follow a more grammar-based and teacher-led approach, so the shift to inquiry-based learning likely felt more novel and empowering. For French learners, who were already accustomed to communicative, task-based instruction, the STEAM project may have seemed less distinct from their usual classroom routines. As a result, the motivational impact was less pronounced, perhaps due to students' expectations for measurable linguistic advancement within familiar instructional frameworks.

The linguistic complexity of the classroom further shaped the outcomes of the project. In group tasks, students frequently reverted to English or Darija to communicate more efficiently, especially when encountering vocabulary challenges. While this code-switching facilitated task completion, it also reduced immersion in the target language, particularly in the French class. However, some students learning Arabic reported increased confidence in using the language beyond the classroom, suggesting that the real-world relevance of the task helped to bridge the gap between formal learning and personal use.

Together, these findings point to the potential of STEAM-based instruction to stimulate short-term engagement and affective motivation in language learning. However, they also highlight the limitations of such interventions when not accompanied by structured opportunities for language development. The contrasting responses from French and Arabic learners underscore the need to tailor interdisciplinary approaches to the sociolinguistic realities of each language and the specific needs and expectations of learners.

As this study was conducted through an action research lens, the dual role of teacher and researcher provided a unique vantage point to observe student reactions and make iterative pedagogical decisions. This position also required a conscious effort toward reflexivity, particularly when interpreting student feedback and affective responses. To support validity, the study incorporated multiple data sources and encouraged students to share their thoughts freely through anonymous surveys and guided discussions. These methods helped to mitigate bias and provided a fuller picture of student experience in the multilingual classroom.

The findings suggest several practical considerations for integrating STEAM into language instruction. Interdisciplinary projects should be paired with clear linguistic goals and scaffolding to support grammar, vocabulary, and oral expression. Open-ended inquiry tasks need to be balanced with structured learning opportunities to ensure learners perceive language progress. In multilingual environments, strategies such as visual prompts and language-use agreements can help maintain consistent target language practice. Additionally, designing STEAM tasks that connect meaningfully with students' cultural and linguistic identities can increase their relevance and impact. Importantly, the novelty of the approach may be more effective when introduced into settings that typically rely on more traditional methods, whereas already communicative classrooms might benefit from stronger emphasis on measurable outcomes.

There are, of course, limitations to consider. The study involved a small group in a single school context, which restricts the generalizability of the findings. A temporary shift to remote learning during the initial phase may have influenced student perceptions and participation. Furthermore, the frequent use of English and dialect Arabic during collaboration likely reduced students' exposure to and use of the target languages throughout the sequence.

Future research could explore how STEAM-based instruction affects language learning in other educational and cultural settings, with attention to different age groups, proficiency levels, and language combinations. Longitudinal studies would also be valuable in assessing the sustainability of motivational changes and their impact on actual language development over time. Investigating how schools and teachers can collaborate across disciplines to implement STEAM more effectively may offer further insight into how this approach can be scaled and adapted for diverse language learning environments.

A key strength of the study lies in its action research design, which enabled context-responsive innovation and student-centered reflection. However, limitations include the small sample size, temporary shift to online learning, and students' tendency to revert to English or dialect Arabic during collaboration. These factors may have reduced target language exposure. Despite this, the study demonstrates that interdisciplinary approaches can enhance learner motivation when instructional design accounts for linguistic diversity, cultural identity, and perceived language utility. The findings reinforce the importance of integrating language-focused scaffolding into STEAM tasks to support both engagement and linguistic development in multilingual settings.

References

American Council on the Teaching of Foreign Languages (ACTFL). (1996). Standards for foreign language learning: Preparing for the 21st century. Yonkers, NY: ACTFL.

Asigigan, SI, & Samur, Y (2021). The effect of gamified STEM practices on students' intrinsic motivation, critical thinking disposition levels, and perception of problem-solving skills. International Journal of Education in Mathematics, Science, and Technology (IJEMST), 9(2), 332-352. https://doi.org/10.46328/ijemst.1157

Bybee, R (1997). Achieving scientific literacy: From purposes to practices. Portsmouth, NH: Heinemann.

Bybee, R, & Landes, NM (1990). Science for life and living: An elementary school science program from Biological Sciences Improvement Study (BSCS). The American Biology Teacher, 52(2), 92–98.

Catchen, R (2013). Reflections ~ How STEM becomes STEAM. The STEAM Journal, 1(1), Article 22.

Cresswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approach. Thousand Oaks, CA: SAGE Publications.

Deci, EL, & Ryan, RM (1985). Intrinsic motivation and self-determination in human behavior. Berlin: Springer.

Dörnyei, Z, & Ottó, I (1998). Motivation in action: A process model of motivation. Working Papers in Applied Linguistics, 4, 43–69.

Dörnyei, Z (2005). The psychology of the language learner: Individual differences in second language acquisition. Mahwah, NJ: Lawrence Erlbaum.

Dörnyei, Z (2009). The L2 motivational self-system. In Z. Dörnyei & E. Ushioda (Eds.), Motivation, language identity and the L2 self (pp. 9-42). Clevedon: Multilingual Matters.

Ellis, R (2010). A framework for investigating oral and written corrective feedback. Studies in Second Language Acquisition, 32(2), 335-349.

Ennaji, M (2005). Multilingualism, Cultural Identity, and Education in Morocco. New York: Springer.

Gardner, RC (1979). Social psychological aspects of second language acquisition. In H Giles, & R St Clair (Eds), Language and social psychology (pp 193-220). Oxford: Blackwell.

Gardner, RC (2010). Motivation and second language acquisition: The socio-educational model. New York: Peter Lang.

Jia, Y, Zhou, B, & Zheng, X (2021). A curriculum integrating STEAM and Maker education promotes pupils' learning motivation, self-efficacy, and interdisciplinary knowledge acquisition. Frontiers in Psychology, 12, 725525. https://doi.org/10.3389/fpsyg.2021.725525

Kolb, DA (1984). Experiential learning: Experience as the source of learning and development. Englewood Cliffs, NJ: Prentice Hall.

Lin, C, & Tsai, C (2021). The effect of a pedagogical STEAM model on students' project competence and learning motivation. Journal of Science Education and Technology, 30(1), 82-94. https://doi.org/10.1007/s10956-020-09885-x

Maamouri, M (1998). Language education and human development: Arabic diglossia and its impact on the quality of education in the Arab region. The Mediterranean Development Forum. Washington, DC: The World Bank

Mater, N, Daher, W, & Mahamid, F (2023). The effect of STEAM activities based on experiential learning on ninth graders' mental motivation. European Journal of Investigation in Health, Psychology and Education, 13(7), 1229-1244. https://doi.org/10.3390/ejihpe13070091

Moore, TJ, Glancy, AW, ..., & Smith, KA (2014). A framework for quality K-12 engineering education: Research and development. Journal of Pre-College Engineering Education Research, 4(1), 1–13. https://doi.org/10.7771/2157-9288.1069

National Research Council (1996). National science education standards. Washington, DC: National Academy Press.

Ng, W, & Fergusson, J (2020). Engaging high school girls in interdisciplinary STEAM. Science Education International, 31(3), 283-294. https://doi.org/10.33828/sei.v31.i3.7

Oxford, R (1990). Language learning strategies: What every teacher should know. New York: Newbury House Publishers.

Pugar, Q, Haristiani, N, & Herniwati (2021). STEAM project-based learning in enhancing Japanese speaking skills in online classrooms. Advances in Social Science, Education, and Humanities Research, 595, 85-91. https://doi.org/10.2991/assehr.k.211119.085

Schoettler, SD (2015). STEM education in the foreign language classroom with special attention to the L2 German classroom (Doctoral dissertation, Portland State University). https://doi.org/10.15760/etd.2310

Svalberg, AM (2007). Language awareness and language learning. Language Teaching, 40(4), 287-308.

Vygotsky, LS (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: MIT Press.

Williams, M, & Burden, R (1997). Psychology for language teachers: A social constructivist approach. Cambridge: Cambridge University Press.

Yakman, G (2008). STEAM education: An overview of creating a model of integrative education. The STEAM Journal, 1(1), 1–10.

Annex - STEAM and French Unit Plan

<table>
<tr><td>Unit title</td><td colspan="3">Biodiversity of birds in the school campus</td></tr>
<tr><td>Unit description</td><td colspan="2">In this unit, students will engage in a scientific process through investigating and monitoring the birds and their habitat in the school campus. They will use observational and thinking skills to develop an action plan, design and refine solutions to benefit the bird's chances of survival in the school environment. This may include planting native plants, installing bird feeders or baths and delivering a school campaign to raise the community's awareness about the importance of birds.</td><td>Time allocation:
Six Weeks (About 10 period lessons).</td></tr>
<tr><td colspan="4">Outcomes</td></tr>
<tr><td>Language/content</td><td>Creativity</td><td colspan="2">Critical thinking</td></tr>
<tr><td>- Learn the vocabulary of birds.
- Learn information about birds (body parts, habitat, food, etc.)
- Develop and poses questions and hypotheses in French for scientific investigation.
- Share background knowledge in French.
- Gather information through French media and texts.
- Compare and contrast traits of birds within the same species and across species.
- Plan an investigation collaboratively to obtain data and information.
- Collect and represents data and information using French and technology.
- Analyze and evaluates data and information.
- Solve real world problems using data, critical thinking, scientific process, and design skills.
- Construct engineering solutions based on criteria and constraints.
- Predict the relationship between the bird traits and the environment.
- Evaluate engineering solutions and revision if necessary.</td><td>- Inquire: Observe, describe relevant experiences, knowledge and information.
- Inquire: Make connections to other concepts and ideas, integrate other disciplinary perspectives.
- Imagine: Explore, seek, and generate ideas.
- Design solutions based on criteria and constraints using non-traditional materials.
- Design solutions based on resolving a problem related to a bird thriving in an environment.
- Reflect and revise solutions based on outcomes.</td><td colspan="2">- Inquire: Identify and question assumptions, become aware of gaps in knowledge.
- Inquire: Understand the context, frame and boundaries of the problem.
- Imagine: Identify and review alternative ideas and compare and imagine different perspectives on the problem.
- Define a problem and justify a solution based on reasoning based on logical solution.
- Reflect on the chosen scientific solution and consider possible alternatives.
- Reflect and evaluate and acknowledge the uncertainty or limits or the solution.</td></tr>
</table>

<table>
<tr><td>- Communicates scientific understanding in French.</td><td></td><td></td></tr>
<tr><td colspan="2">Resources:
- Documentary video about endangered birds.
- Reading text from the book “The silent spring” by Rachel Carson.
- Images and flashcards of common birds in the region.
- Websites about birds.
- Equipment for the investigation (I Pad, camera, notebook ...)
- Apps (birdNet, Merlin bird ID ...)
- Worksheets (Investigation journal, Master plan, etc.)</td><td>Assessment:
- Bird feeder’s project and presentation.</td></tr>
<tr><td>Content areas:
- Science
- Math
- Geography
- Engineering/design
- French
- Art</td><td colspan="2">Essential inquiry questions
- How can we improve the biodiversity of birds in our school campus?
- Which species of birds can we find in our school campus?
- How can we inquiry what are the most common species of birds in the school’s campus?
- What is the biodiversity of birds in our school campus?
- What do the birds in our campus eat?
- Why do the birds have different beaks?
- Did the biodiversity of birds improve in our campus thanks to the feeders?</td></tr>
<tr><td colspan="3">First loop</td></tr>
<tr><td colspan="2">Phase 1: Engage the students in the topic of birds and biodiversity.</td><td>Inquiry question: How can we improve the biodiversity of birds in our school forest?</td></tr>
<tr><td colspan="2">Activities:
- Listening activity: Students watch a documentary about endangered bird species and answer the comprehension questions.
- Reading activity: Students read a passage from the book « Silent Spring » by Rachel Carson and answer the comprehension questions.
- Thinking and discussion: Students use their prior knowledge to:
o Draw a mind map about the impact of the D.D.T. spray on the environment.
o Discuss the relationship between humans’ actions and the birds’ extinction.
- Problem introduction: Through the discussion, the students are introduced to the problem they will solve: At school, we have a beautiful forest that birds visit. What can we do to protect these birds and improve their biodiversity?</td><td>Resources:
Link:
https://enseigner.tv5monde.com/fiches-pedagogiques-fle/le-coq-de-bruyere
Worksheets:
- Endangered birds listening activity.
- Silent Spring - French reading text.</td></tr>
<tr><td colspan="2">Phase 2: Students explore their ideas about the biodiversity of birds in the school’s forest.</td><td>Inquiry question: Which species of birds can we find in our garden?</td></tr>
<tr><td colspan="2">Activities:
- Discussion:
o In (1-2-4) cooperative groups, students look at a set of cards representing a variety of birds and choose the ones they think are the most common in the school forest.
- Inquiry activity:
o Students engage in a thinking activity and fill the two first columns of the I-chart. (What do we know about birds? /What do we want to know about birds)</td><td>Resources:
- Bird flashcards.
- Inquiry chart.</td></tr>
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<table>
<tr><td>Phase 3: Language scaffolding
<u>Vocabulary:</u> Students learn the birds body parts through an interactive activity.
- They will match the pictures and names.
<u>Grammar:</u> Students learn how to agree nouns and adjectives in singular, dual and plural.
- Students will look at a photo of an owl and share what they know about the bird.
- Using (1-2-4) strategy, they will complete text with adjectives from the chart.
- They will discuss their choices with the group.
- They will try to come up with the rules.
- They will practice through a writing activity.</td><td>Inquiry questions:
- How can we name the bird's body parts in French?
- How can we agree nouns and adjectives in French?
- How can we write a descriptive text?

Resources:
Vocabulary: https://wordwall.net/resource/34175182
Grammar worksheet: Grammar activity- Adjective agreement</td></tr>
<tr><td>Phase 4: Students acquire opportunities to connect their previous knowledge with current learning.</td><td>Inquiry question: How can we inquiry what are the most common species of birds in the school's forest?</td></tr>
<tr><td colspan="2">Activities: In groups, students design and plan for the scientific investigation taking in consideration:
- The area they choose to investigate.
- How many times per week they will observe.
- How they can create the school map.
- The tools they will use for the investigation.
- How they will divide the different investigation tasks.
- How they can collect the data.
In order to help the students, they will be given the investigation's journal to fill (pages 2-5).</td><td>Resources:
-Investigation journal</td></tr>
<tr><td>Phase 5: Students apply or extend previously introduced concepts and experiences to new situations.</td><td>Inquiry question: What is the biodiversity of birds in our school forest?</td></tr>
<tr><td colspan="2">Activities: In groups, they carry out their scientific investigation:
- Create the school map:
o In groups, students create a map of the school. They will draw and label the land types, buildings and boundaries, they will also include a map key and the compass rose.
o Once the students have mapped the school, they can choose one area to investigate (front area or back area).
o The chosen area can be divided into sections, with different student pairs assigned to each section. Finally, each pair will write a short description of their assigned area in the investigation journal.
- Wonder and observe: Students conduct an observational study; they will take a short walk around the school campus during which they are invited to find a spot to explore using their senses and the technological tools (camera, I Pads, Mobile apps etc).
- Collect data: They record what they notice in the observation worksheet, they take pictures of the birds they can see and the different habitat, they record the birds' sounds that they hear and analyze them with the bird watching apps in order to identify the different species.
- Analyze data: In groups, they create graphs to communicate data about the birds.</td><td>Resources:
- Investigation journal.
- Observation sheets
- Camera.
- Mobile
- I pad
- Mobile apps (BirdNet, Merlin bird ID)</td></tr>
<tr><td>Phase 6: Students reflect on their learning and represent the changes to their ideas and beliefs.</td><td>Inquiry question: How can we communicate our results?</td></tr>
<tr><td colspan="2">Activities:
In groups, students present their results using presentations or posters.</td></tr>
<tr><td colspan="2">Second loop</td></tr>
<tr><td>Phase 1: Students revisit again the main question.</td><td>Inquiry question: How can we improve the biodiversity of birds in our school forest?</td></tr>
<tr><td colspan="2">Activities:
Based on the investigation's findings, the students discuss how to improve the biodiversity of birds in the school's forest.</td></tr>
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<table>
<tr><td colspan="2">Phase 2: Students explore their ideas about the food that the birds need.</td><td>Inquiry question: What do the birds in our forest eat?</td></tr>
<tr><td colspan="2">Activities:
- In (1-2-4) cooperative groups, students look at a set of cards representing birds in the forest and other common bird species in the area. Then, they classify them according to their main food.</td><td>Resources:
- Bird flashcards.</td></tr>
<tr><td colspan="2" rowspan="2">Phase 3: Language scaffolding
<u>Vocabulary:</u> Students will learn vocabulary related to the birds' nutrition.
- They will read and study the vocabulary list.
- They will classify birds according to their food.
- They will watch short videos of birds while eating and will describe them using the vocabulary.
<u>Grammar</u>: Give information about reasons and purpose.
- Students will read a short explanatory text about birds' nutrition.
- They will underline the sentences that express reasons and purpose.
- They will determine the key words that introduce the reasons and purpose.
- Discuss their findings with a partner and share with the group.
- They will compare the structure of the sentences and come up with a grammatical rule.
- They answer few "why?" questions to practice and reinforce their learning.</td><td>Inquiry questions:
- What do birds eat?
- How can I speak about bird's food in French?
- How do birds find their food and eat it?
- How can I explain reasons and purposes in French?</td></tr>
<tr><td>Resources:
Vocabulary list on Quizlet:
https://quizlet.com/gb/1006238437/bird-nutrition-flash-cards/?i=4jqvv&x=1jqt
Birds eating:
https://www.youtube.com/watch?v=gAU0lGMJkVg
Grammar:
Worksheet: Grammar - Express reasons</td></tr>
<tr><td colspan="2">Phase 4: Students develop deep understanding about the beak adaptations in bird populations and looks at the way in which variation in beak shape is related to the available food sources within an environment.</td><td>Inquiry question: Why do the birds have different beaks?</td></tr>
<tr><td colspan="2">Activities:
- Simulation experiment: Battle of the beaks
o Students simulate bird feeding by using a 'beak' to collect food and place it into a stomach.
- Reflection and research:
o Students research information about bird's feeders.</td><td>Resources:
Worksheet: Beak and food</td></tr>
<tr><td>Phase 5: Students apply their learning to design and make birds feeders with awareness of birds' variations:
- Seed-eating birds.
- Fruit-eating birds.
- Insect-eating birds.</td><td colspan="2">Inquiry question: What is the biodiversity of birds in our forest?</td></tr>
<tr><td colspan="2">Activities:
- Brainstorming: In groups, students brainstorm ideas about how to construct a functional bird's feeder for each birds' variation:
o Seed-eating birds.
o Fruit-eating birds.
o Insect-eating birds.
- Discussion: Students present their designs and justify their choices.
- Develop a plan: After they agree on the best feeder designs, they want to make, they develop a plan that includes materials, birds' locations, and timeline.
- Fundraise the money and collect the needed materials.
- Design and make the feeders.
- Feeders' installation: Students install the birds' feeders in various places in the school campus and monitor them regularly.</td><td>Resources:
- Project master plan.
- Materials to make the feeders.</td></tr>
<tr><td colspan="3">Phase 6: Students present their prototypes using presentations or posters. They will make sure to justify their choices.</td></tr>
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<tr><th colspan="2">Third loop</th></tr>
<tr><td>Phase 1: Students revisit again the main question.</td><td>Inquiry question: Did the biodiversity of birds improve in our forest thanks to the feeders?</td></tr>
<tr><td colspan="2">Activities: The students will make weekly visits to the feeders to make observations and collect data.</td></tr>
<tr><td>Phase 2: Students check on their solution and record whether the bird feeders worked as expected, to attract more birds. They should discuss how to find evidence of birds having been at their bird feeders. Then, they can discuss possible modifications to the solutions, if needed.</td><td>Inquiry question: What do you think about the change of the birds' biodiversity?</td></tr>
<tr><td>Phase 3: Language scaffolding
Writing: Narrate and describe past events.</td><td>Resources:
- Practice narrating past events (Worksheet)</td></tr>
<tr><td colspan="2">Phase 4: Students acquire opportunities to connect their previous knowledge with current learning.</td></tr>
<tr><td>Activities:
- Create a plan: In groups, students plan an investigation to measure the changes in birds' biodiversity.</td><td>Resources:
- Master plan</td></tr>
<tr><td>Phase 5: Students apply or extend previously introduced concepts and experiences to new situations.</td><td></td></tr>
<tr><td>Activities:
- Observation: Students observe the birds' movement around the feeders, or they can install cameras to record birds' movements.
- Collect data: They record what they notice in the observation worksheet.
- Analyze data: In groups, they create graphs to communicate data to determine how birds are affected by resource availability.
- Evaluation: They evaluate the efficacy of the feeders.</td><td>Resources:
- Master plan: Observation sheet (n° 8)</td></tr>
<tr><td colspan="2">Phase 6: Present the result and share your story.</td></tr>
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