

The Śabdabrahman exercise platform

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Abstract

The Śabdabrahman exercise platform (SBE), at sabdabrahman.org, is an on-line interactive Sanskrit instructional platform that offers immediate feedback and focused help to students at every step of analyzing and translating the Sanskrit sentences in a first-year Sanskrit textbook. Steps include transliteration from Devanagari to standard Romanization and vice versa, analysis of sandhi, identification of nominal and verbal inflection, syntax, compound analysis, and translation. Student submission at each step is evaluated, errors highlighted, and links supplied to relevant help. Source documents are prepared in XML in accordance with the Text-Encoding Initiative guidelines. The platform is coded in Flask and ReactJS and hosted at Amazon Web Services (AWS). The platform has been successfully used in first-year Sanskrit courses offered through The Sanskrit Library (sanskritlibrary.org).

1 Introduction

The decline of systematic instruction in Sanskrit and the increase of superficial conversational Sanskrit instructional materials dissappoint students who seek an introduction to the depth and complexity of the Sanskrit language and literature. The result is that students fail to be introduced to genuine historical texts so go from “I don’t know” to “I don’t care”. Nevertheless, it is possible to use digital technology in an intelligent way to engage enthusiastic students in the beauty and depth of Sanskrit in a rigorous manner. The Śabdabrahman exercise platform (SBE), accessible at sabdabrahman.org, is an interactive platform that leads students through every step of understanding and translating into English the Sanskrit sentences in the first-year Sanskrit textbook by Scharf (2022a) while providing detailed feedback and focused help. The platform is currently available to students enrolled in first-year Sanskrit courses at the Sanskrit Library sanskritlibrary.org/courses.html. Soon to be added to the platform are the verses and prose paraphrases of them by Scharf (2022b) for second-year Sanskrit students. Śabdabrahman is a dynamic platform that combines a rich repository of resources with interactive tools. In an age where digital technologies have reshaped educational paradigms, this website offers an unparalleled opportunity to delve into the rich tapestry of Sanskrit literature and linguistics. We shall navigate through the various facets of Śabdabrahman, elucidating its architecture, key features, and the user experience it offers.

2 Motivation

In a first-year Sanskrit course outside of India, as in the first-year course in any ancient language, or in any language course that focuses on developing the ability to read texts, students are confronted with several aspects of the language at once: script, phonetics, morphology, syntax, and semantics. In daily homework assignments, Sanskrit students transcribe from Devanagari to Roman script with diacritics, analyze inter-word prosodic changes (*sandhi*), identify the inflection of each word, that is, the declension of nominal forms and conjugation of finite verbs, analyze the syntactic structure of each sentence and translate. In a homework set which typically

consists of thirty or more sentences, the student might repeatedly encounter the same difficulty or make the same mistakes. However, the student has no opportunity to clarify his understanding or correct his mistakes until he submits the homework assignment and the instructor corrects it and hands it back days or perhaps a week later. Lingering doubt and repeated errors lead to frustration on the part of the student. The instructor too typically spends hours correcting the students' transcription from Devanagari to Roman script with diacritics, analysis of inter-word prosodic changes (sandhi), inflectional identification, syntax, and translation. The correction of the first several steps is extremely time-consuming and tedious. Frequently students proceed to a new exercise set before they receive corrections on their first set; hence they often repeat the same mistakes, not only within an exercise set but also in subsequent sets, leading to further frustration. The instructor, to his exasperation, therefore has to repeat the same comments numerous times. Moreover, because the student receives comments on the first set several days after completing it, due to the delay he might no longer recall the context of instructor comments so might not attend to the correction with due attention. In short, the information lag makes learning inefficient.

Ideally it is desirable for the student to receive immediate focused feedback on each step of each sentence in each exercise set, that is, to receive immediate confirmation of correct work, to receive immediate focused pin-pointing of mistakes, and to be directed to and have immediate access to relevant information to explore issues about which he has doubt or confusion. We have developed an on-line interactive exercise platform that offers these features.

Most currently available language learning software is oriented towards teaching business and travel themes for aural/oral communicative use of modern languages (Murray and Barnes 1998: 253). Popular apps such as DuoLingo, Rosetta Stone, Babbel, Pimsleur, etc. are all geared toward these goals. The development of comprehensive language-learning software involves assembling numerous experts and is an expensive undertaking from conception and design to implementation and evaluation (Turel and McKenna 2014: 1200). The development of comprehensive language-learning software for classical culture-bearing languages is slim. The system we have developed is unprecedented.

3 Overview of the Śabdabrahman exercise platform (SBE)

The interactive Śabdabrahman exercise platform (SBE) provides the student with immediate focused help at each stage of working through a sentence. This help enables the student to correct his own mistakes. The platform does not provide the correct answer but rather pinpoints the error and provides links to assistance. Each stage of working through a sentence is dealt with in a separate pane. Each pane has a sidebar provided with links to appropriate help and also evaluates the student's submitted work.

First the platform asks the student to transcribe the Devanagari sentence (Figure 1). It then compares the student's transcription of Devanagari with the correct transcription and highlights differences (Figure 2). The highlighted error is linked to an appropriate document: a page showing simple signs or dependent vowel signs and their Romanization, or a page showing conjunct consonant signs.

Once the transcription is correct, a confirmation message is given and the student is presented with the second pane where he is asked to analyze sandhi. SBE implements sandhi on the student's sandhi-analysis, compares the result with the original question and highlights the errors in red (Figure 3). Where doing sandhi to the student's sandhi-analysis does reproduce the correct original, but the analysis is erroneous or insufficient, SBE compares the student's sandhi-analysis with the correct analysis, highlights differences in blue and displays brief instructions upon mouse-over (Figure 4). Clicking on the highlighted differences links to the appropriate sandhi table.

Once the sandhi analysis is correct, a confirmation message is given and the student is presented with the third pane in which he is asked to select the words' lemma, i.e. the root of

Figure 1: SBE transliteration question

Figure 2: SBE transliteration error highlighting

Figure 3: SBE sandhi analysis pane with highlight errors

Home Chapters Students Bhartrhari Logout

Chapter 18 / Exercise 1 / Question 1 / Sentence 1

Transliteration Sandhi analysis Identification Syntax Translation

Your analysis of sandhi is not entirely correct. We have applied sandhi to your analysis and transli... See more

Q: तावद्रात्रिः क्रमते यावत्सूर्यो नाक्रमते।
tāvadrātriḥ kramate yāvatsūryō nākramate.

A: तावद्रात्रिः क्रमते यावत्सूर्यो नाक्रमते।
tāvadrātriḥ kramate yāvatsūryō nākramate.

tAvap rAtriH kramateH yAvatsUryaH na akramate.

Check

Next

Error index

- Wrong analysis
- Insufficient analysis

Help

- SLP1 encoding
- Phonological features
- Sanskrit segments
- Additional phonological categories
- Consonant pre-pause allophones
- Vowel sandhi
- Consonant sandhi
- Final stop sandhi

Figure 4: SBE sandhi analysis pane with highlight errors and mouse-over message

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Chapter 18 / Exercise 1 / Question 1 / Sentence 1

Transliteration Sandhi analysis Identification Syntax Translation

Your analysis of sandhi is not entirely correct. We have applied sandhi to your analysis and transli... See more

Q: तावद्रात्रिः क्रमते यावत्सूर्यो नाक्रमते।
tāvadrātriḥ kramate yāvatsūryō nākramate.

A: तावत् रात्रिः क्रमते यावत्सूर्यः न क्रमते।
tāvāt rātriḥ kramate yāvatsūryaḥ na kramate.

tAvat rAtriH kramate yAvatsUryaH na akramate.

Check

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Wrong analysis

The highlighted characters are incorrect or superfluous.

each finite verb or the stem of each nominal, from a glossary, choose its correct lexical category, and enter its inflectional identifier (Figure 5). A dialogue box that shows the possible options for each parameter assists with inflectional identification if desired (Figure 6). Experienced students can simply type the inflectional identifier in the text box. The morphological identification of each word can be checked individually or all at once. Incomplete items and mistakes are flagged (Figure 7). If the student has selected a root or stem but made an error in its inflectional identification, SBE provides a link to the inflectional paradigm appropriate to the selected stem.

When the student has correctly identified all of the inflectional morphology, SBE provides a confirmation message and the student can proceed to the fourth pane in which he is asked to analyze the syntax of the sentence, and the fifth pane in which he is asked to translate the sentence. He is free to move between the syntax and translation panes. Syntactic relations are divided into two classes: primary and secondary. Primary relations include identification of the main verb of a clause and relations denoted by nominal declension such as *kāraka* relations, qualification, and possession. Secondary relations include predication, and relations indicated by particles such as conjunction, alternation, and contrast. We save detailed discussion of these syntactic relations for another occasion. For each word, the student selects the primary or secondary relation, and the target or targets of the relation. A target is another word in the sentence to which the word is subordinate in that relation. Relations are selected by flex search from a list of relations that are possible for the given item, and targets are selected by flex search from a list of words in the sentence. Errors are flagged when the student checks. Once primary relations are correct, SBE makes available a graph showing primary relations, or, if all relations are correct, a graph showing both primary and secondary relations (Figure 8). Primary relations are shown in gold with blue arrows to their targets; secondary relations in silver with green arrows to their targets.

The translation pane presents the student with all of the information he has previously completed correctly to assist him in composing his translation as well as a brief translation of each lemma as given in the glossary (Figure 9). When the student enters a translation in the translation pane text box, SBE checks for a match against the possible correct translations provided. If it does not match any, SBE verifies whether all necessary terms have been included or not, calculates the closeness to the correct translation, and provides an appropriate message. If the student simply enters the word translations provided, SBE recognizes the translation as incomplete (Figure 10). SBE also includes nominal, verbal, and participle identification drills, and compound analysis not shown here.

All answers including translations are saved and made available to the instructor to go over with the students in their subsequent meeting. SBE itself provides entirely complete feedback to the student on all clearly categorical steps, but the translation may involve subtle nuances beyond the scope of currently available technology to evaluate. The instructor may view just the translation, or additional steps so that they may be shown to students for explanatory purposes in class meetings (Figure 11). SBE tracks the completed exercises of each student for both the student's benefit, and the instructors evaluation. Percentages are displayed of completed questions within each exercises, lesson, and text.

4 Source

The questions and correct answers are prepared in a set of coordinated XML files structured in accordance with the Text-Encoding Initiative guidelines. Scharf (2018) discusses and illustrates the general features of the TEI markup of verses and their constituent verse quarters and words. Ajotikar and Scharf (2023) describe the use of TEI to mark up commentaries. The Search and Retrieval of Indic Texts (SARIT) Website includes detailed guides to how to structure a Sanskrit text in accordance with the TEI Guidelines under the About SARIT menu <https://sarit.indology.info>. Hence we pass over detailed description of the structure within each

Figure 5: SBE identification pane with lemma flex search

Home Chapters Students Bhartrhari Logout

Chapter 18 / Exercise 1 / Question 1 / Sentence 1

Transliteration Sandhi analysis Identification Syntax Translation

Now identify the inflection, lemma, and lexical category of each word in the boxes so labeled. Input ... See more

Q: तावत् रात्रिः क्रमते यावत् सूर्यः न आक्रमते।

A:

<p>तावत्</p> <p>Inflection Third</p> <p>Lemma t</p> <p>taMsyat taMsyamAna tata tatavat tatas</p> <p>Inflection i</p> <p>Lemma yAvat</p> <p>Lexical category rel_adv</p> <p>Check</p>	<p>रात्रिः</p> <p>Inflection f1s</p> <p>Lemma rAtri</p> <p>Lexical category f</p> <p>Check</p>	<p>क्रमते</p> <p>Inflection pre_m3s</p> <p>Lemma kram</p> <p>Lexical category vt1am</p> <p>Check</p>
<p>सूर्यः</p> <p>Inflection m1s</p> <p>Lemma sUrya</p> <p>Lexical category m</p> <p>Check</p>	<p>न</p> <p>Inflection i</p> <p>Lemma na</p> <p>Lexical category neg_pcl</p> <p>Check</p>	

Help

- Present-system verbal terminations
- Present-system verbal stem classes
- Class 3 present-stem derivation
- Perfect verbal terminations
- Verbal identification
- Nominal identification
- Case meaning

Figure 6: SBE identification pane with inflection identification dialogue box

Home Chapters Students Bhartrhari Logout

Chapter 18 / Exercise 1 / Question 1 / Sentence 1

Transliteration Sandhi analysis Identification Syntax Translation

Now identify the inflection of the following word.

Q: क्रमते

A:

क्रमते

Nominal Verb

Root type

- primary
- c causitive
- d desiderative
- i intensive

Tense

- pre present
- ipf imperfect
- ipv imperative
- pop present optative
- pij present injuctive
- fut future
- con conditional
- pft periphrastic future
- prf perfect
- aor aorist
- aop aorist optative
- aij aorist injuctive

Voice

- a active
- m middle
- p passive

Person

- 1 first
- 2 second
- 3 third

Number

- s singular
- d dual
- p plural

Submit Close

Lexical category rel_adv Check

Lexical category m Check

Lexical category neg_pcl Check

Help

sent-system verbal minations

sent-system verbal m classes

ss 3 present-stem ivation

fect verbal minations

Verbal identification

Nominal identification

Case meaning

Figure 7: SBE identification pane error flagging

Home Chapters Students Bhartrhari Logout

Chapter 18 / Exercise 1 / Question 1 / Sentence 1

Transliteration Sandhi analysis Identification Syntax Translation

Please fix the errors marked in red. If the lemma is correct but its inflection wrong, click its red... See more

Q: तावत् रात्रिः क्रमते यावत् सूर्यः न आक्रमते।

A:

<p>तावत्</p> <p>Inflection: i</p> <p>Lemma: tAvat</p> <p>Lexical category: dem_adv</p> <p>Check</p>	<p>रात्रिः</p> <p>Inflection: f1s</p> <p>Lemma: rAtri</p> <p>Lexical category: f</p> <p>Check</p>	<p>क्रमते</p> <p>Inflection: Third</p> <p>Lemma: kram</p> <p>Lexical category: vt1am</p> <p>Check</p>
<p>यावत्</p> <p>Inflection: i</p> <p>Lemma: yAvat</p> <p>Lexical category: rel_adv</p> <p>Check</p>	<p>सूर्यः</p> <p>Inflection: m1s</p> <p>Lemma: sUrya</p> <p>Lexical category: m</p> <p>Check</p>	<p>न</p> <p>Inflection: i</p> <p>Lemma: na</p> <p>Lexical category: neg_pcl</p> <p>Check</p>

Help

- Present-system verbal terminations
- Present-system verbal stem classes
- Class 3 present-stem derivation
- Perfect verbal terminations
- Verbal identification
- Nominal identification
- Case meaning

Figure 8: SBE syntax tree with primary and secondary relations

Home Chapters Harsha Pamidipalli Logout

Chapter 18 / Exercise 1 / Question 1 / Sentence 1

Transliteration Sandhi analysis Identification Syntax Translation

Now identify the main v

Q: तावत् रात्रिः क्रमते

A:

Syntactic role: अत्यन्तसंयुक्तकाल

Parent: क्रमते

Help

- Case meaning
- Case use summary
- Glossary

Figure 9: SBE glossary

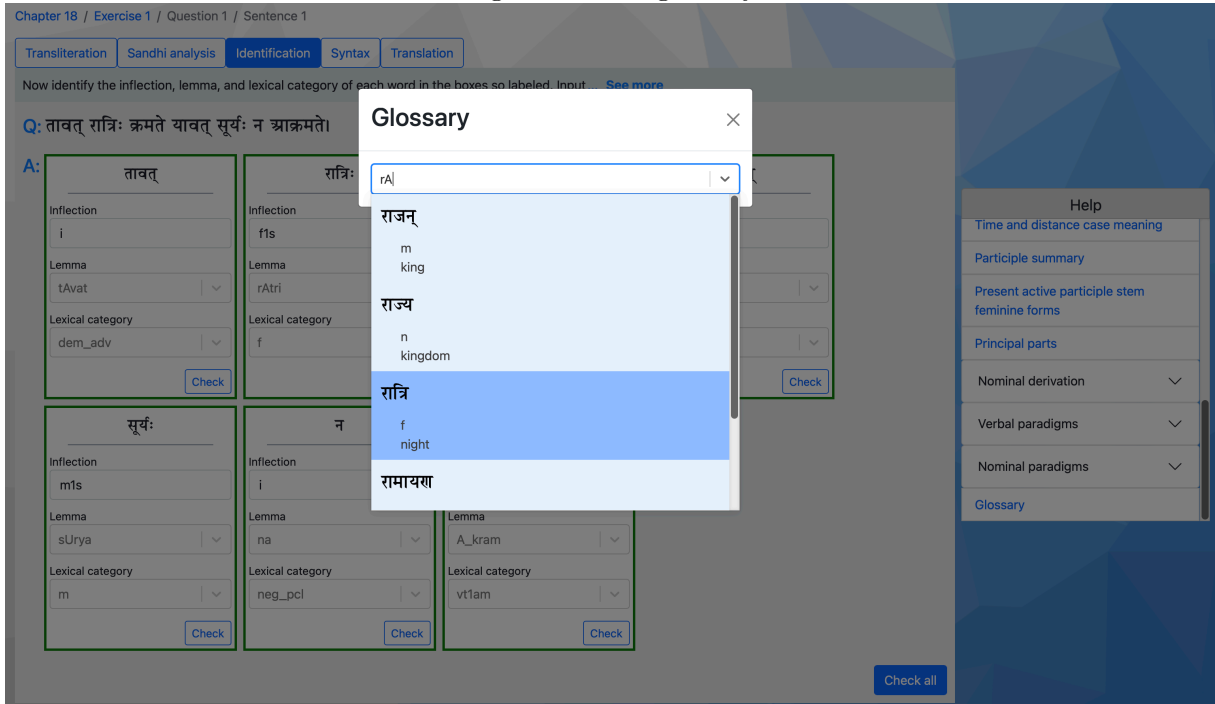


Figure 10: SBE translation pane recognizing an incomplete lemma-only translation

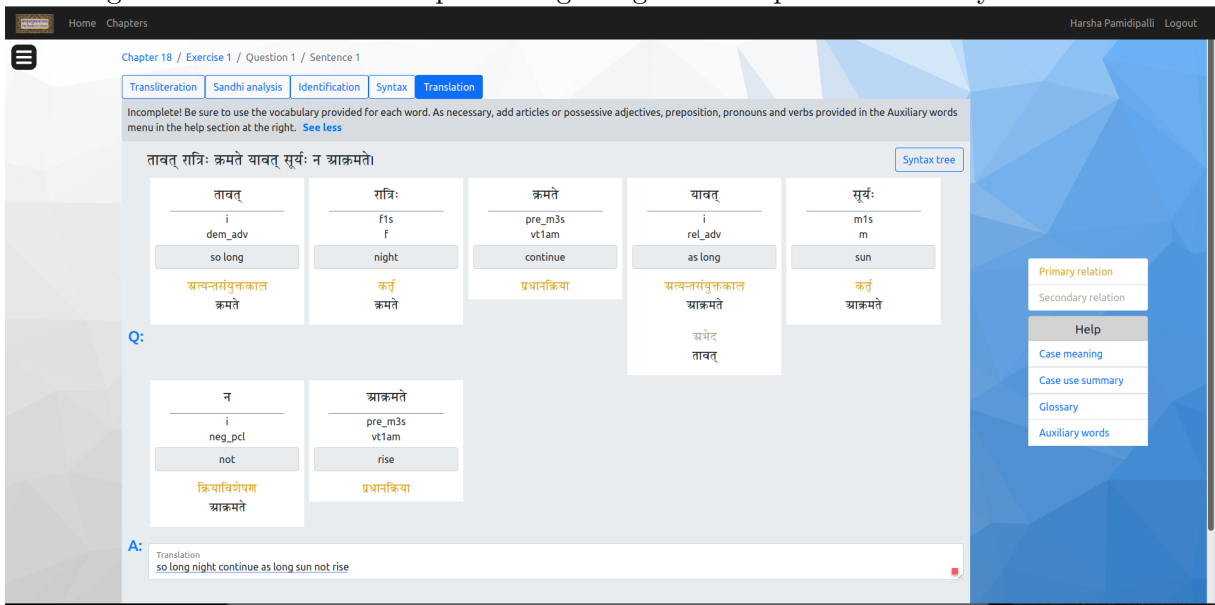
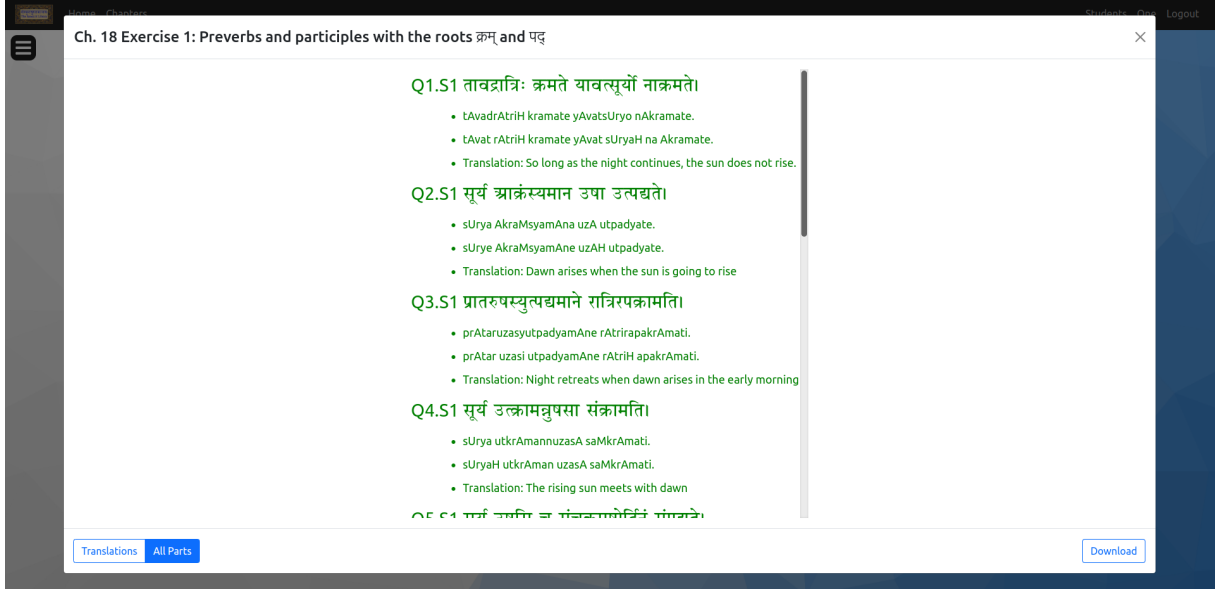


Figure 11: SBE instructor view of student's answers



file in the set of files that constitute the source of the Śabdabrahman platform but instead just briefly describe the files and their relation. Necessary files include a morpheme file, a morpheme translation file, and an English translation file. Files are coordinated using the xml:id of each sentence, word, and morpheme as key. In the morpheme file each sentence is analyzed into words and their constituent morphemes, each word is provided with an inflectional identifier and syntactic relation attributes, and each morpheme is given a lexical identifier. A sandhi-analyzed sentence file, and question file can be produced programmatically from the morpheme file by assembling words in sequence and applying sandhi between them. In fact the files were initially created in the opposite order, that is, by manually analyzing sandhi in a question file to produce a sandhi-analyzed sentence file, then programmatically creating a word file with blank attributes for morphological and syntactic identification and morphemic analysis, then manually filling in those blanks.

5 Website structure

SBE is structured like Scharf (2022a), the first-year Sanskrit text book *Śabdabrahman: a linguistic introduction to Sanskrit*, on which it was initially based. This structure makes it intuitive for users to navigate, access content, and engage with the platform. This section provides an in-depth exploration of the website's structural framework, elucidating its hierarchy, navigation, and organizational principles.

5.1 Hierarchy and navigation

SBE adopts a well-structured hierarchy that facilitates intuitive navigation for users. The website's hierarchy includes the following features:

Navigation Bar: Provides quick access to key sections such as homes, chapters, and user profiles.

Menus: A simple main menu and sub-menus within each main section enable users to drill down to specific content and help.

Internal links: Hyperlinks and breadcrumbs connect related content within and across pages, enhancing user navigation.

5.2 Sections and pages

The website is divided into the following distinct sections, each dedicated to a specific aspect of Sanskrit learning and exploration:

Home: A simple landing page displays a welcome message and a link to the Chapters section.

Chapters: A top-level menu displays all the chapters. Each chapter shows the exercises included in it, and each exercise shows the questions within it.

Resources: A menu provides access to a repository of textual and multimedia resources, including classical Sanskrit texts, translations, pronunciation guides, and dictionaries at The Sanskrit Library (sanskritlibrary.org).

User profiles: Users can create and manage their profiles and track their progress. Teachers have access to student exercises and their progress.

Each section contains multiple pages, ensuring comprehensive coverage of topics and resources related to Sanskrit studies.

5.3 Sitemap and diagrams

To provide a visual representation of the website's structure, an illustrative sitemap and diagrams are included in this section. These diagrams offer a bird's-eye view of how various pages and sections are interconnected.

5.4 User-centric design

The website's structure is designed with the user experience in mind, ensuring that learners, regardless of their familiarity with Sanskrit, can easily find, access, and engage with content. User feedback and usability studies have played a crucial role in refining the website's structure, leading to an intuitive and learner-friendly interface.

5.5 Key features and functionalities

The following are the core features and functionalities that define the user experience in SBE:

Intelligent help: SBE provides intelligent and extensive feedback when a user makes a mistake.

Software not only evaluates and classifies errors but also highlights them and links to apt help. This enables the user to strengthen his understanding of the relevant concept and submit the correct answer.

Interactive exercises: To enhance the learning experience, SBE provides interactive tools and resources.

Glossary: A comprehensive, searchable dictionary with part-of-speech lexical identification, and translation of every word in the text.

User-friendly input tools: Dialogue boxes and flex lists ease the users selection.

These resources empower learners to increase their understanding and hone their language skills in a hands-on manner.

6 User experience

In this section, we examine the user-centric design of SBE, focusing on how the website's layout, design, and interactive elements contribute to an effective and enjoyable Sanskrit learning journey. A user-centric approach is integral to the website's success in catering to a diverse audience.

Intuitive navigation: SBE prioritizes user-friendly navigation, ensuring that learners of all levels can easily find their way around the website. The clear and organized menu structure guides users to the resources, courses, and community features they seek. Intuitive breadcrumbs, internal links, and a user-friendly search function further enhance navigation.

Responsive design: SBE employs a responsive-design approach, adapting seamlessly to various devices, including desktops, tablets, and smartphones. This flexibility ensures that users can engage with Sanskrit learning content on their preferred devices, promoting accessibility.

Clear course progression: Courses in SBE are structured with a clear progression, allowing users to systematically advance their Sanskrit language skills. Learners can easily track their progress through modules, lessons, and exercises, motivating them to continue their studies.

Interactive Learning: Interactive elements, such as quizzes, exercises, and pronunciation guides, actively engage users in the learning process. These features reinforce comprehension and retention while maintaining an engaging and dynamic learning environment.

User profiles and progress tracking: User profiles in SBE empower learners to monitor their progress, view achievements, and set personalized learning goals. Progress tracking not only motivates users but also allows them to pick up where they left off in their Sanskrit studies.

The user experience in SBE is thoughtfully designed to cater to a wide-ranging audience, from beginners to advanced scholars. By offering intuitive navigation, and interactive learning tools, the website promotes a positive and engaging environment for Sanskrit enthusiasts. In the following sections, we will explore the technical aspects, including the technology stack and any notable achievements in enhancing the user experience.

7 Technical details

This section delves into the technical underpinnings of SBE, shedding light on the technologies, infrastructure, and considerations that enable the website to function seamlessly. Understanding these technical aspects provides valuable insights into the website's robustness and scalability.

7.1 Technology stack

SBE leverages a well-defined technology stack to deliver its services. Key components may include:

ReactJS: The user interface is built using the Javascript framework ReactJS. A responsive and interactive frontend has been developed making use of its own bootstrap and many supported libraries.

Flask: Python programming language's Flask framework has been used to develop the backend. A REST API is created to enable interaction between the client (frontend) and the server (backend).

Database system: An SQLite database is used to store all the data pertaining to the questions, exercises, and chapters. User information and their answers are also stored here. Flask's SQL Alchemy is used to interact with the database.

Web server: Amazon Web Services (AWS) is used to host both the frontend and backend.

7.2 Hosting and infrastructure

SBE operates on a reliable hosting infrastructure, ensuring high availability and performance. Key aspects to consider include:

Hosting provider: Amazon Web Services (AWS) is the hosting provider. The website is deployed in the cloud using Amazon's Elastic Compute Cloud (EC2) instance. EC2 provides scalable computing capacity as a virtual server. At present SBE is hosted on a t4g.small EC2 instance.

Server specifications: The t4g.small instance provides 2 virtual CPUs and 2 GB of RAM. This instance is powered by AWS Graviton2 processors, which are based on 64-bit Arm Neoverse cores. Amazon's Elastic Block Store (EBS) is linked with the instance to get a storage capacity of 25 GB.

Scalability: T4g.small instances provide baseline CPU performance that can temporarily burst to handle increased workloads. One can customize scaling behavior to match the application’s needs or enable autoscaling, which will duplicate the instance to handle greater load.

Security measures: Security is paramount for SBE. The security measures in place to protect user data include:

SSL encryption: A library named certbot is used to generate an SSL certificate. An SSL certificate is crucial to secure data during transmission over the internet. It provides data privacy, integrity, and authentication, which are essential for online security, trust, and regulatory compliance.

User authentication: Google’s Firebase is used to authenticate users with email and password. A simple graphic User Interface (GUI) helps the professor or administrator create multiple user accounts at once. Once a user’s account is created, the user is notified and given a temporary password. Users can log in with this and change their password.

7.3 Maintenance and updates

Through regular testing and feedback from the users, we make many revisions and upgrades to the website. In order to update the website securely, we minimized the room for human error by automating the whole process. We have a bash script in place that will take backups and sync all the files with the server. Apart from this, we backup our database every day and maintain the last three days’ backups.

The whole project is maintained on Github for version control. All the updates and changes are logged as and when an update is made to the website. Appropriate comments and documentation help maintain a clear and transparent record of all the changes to the website.

8 Use

The SBE system has been used already by eighty-eight students in several courses with glowing evaluation. The principal advantages are that SBE provides immediate focused feedback, makes help easily accessible, and interaction with it is engaging, makes learning more fun, and allows more effective use of class time. One student summed up his experience in the Sanskrit Library’s first-year Sanskrit class using the Śabdabrahman exercise platform as follows:

How refreshing to have instant and definitive responses to questions! As you work through assigned transliteration, sandhi, and parsing you get feedback virtually immediately. And the volume of exercises assigned ensures that newly-learned material is reinforced.

I have found SBE’s quick feedback invaluable for learning the basics of the language, allowing for solid progression in a much more time-efficient way than in a traditional classroom. With SBE, time in class with the professor (via Zoom) can be more productively focused on exploring deeper principles, instead of learning basics. The dynamic of SBE-plus-classroom meetings enhances overall progress, making the learning of Sanskrit more fulfilling and satisfying than pure self-study alone. I felt like I had been walking for a long time on the side of the road, and then someone stopped their car and gave me a ride.

9 References

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